Sleep Deprivation and Circadian Desynchrony:

Managing Sleep Sustains Operational Performance

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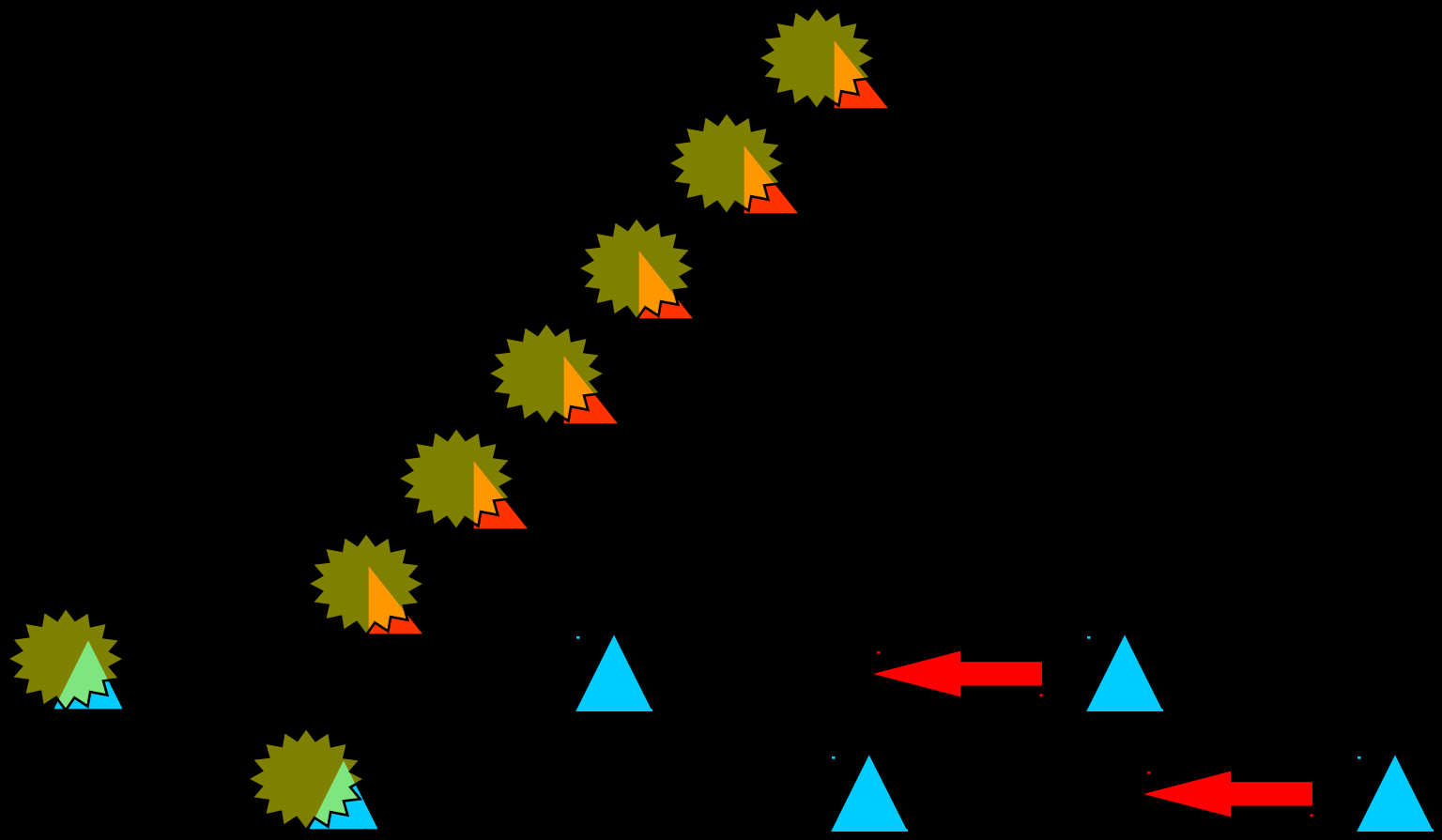
Why are Sleep and Circadian Rhythms Relevant to the U.S. Military?

CASE HISTORY from the GULF WAR

Friendly Fire Incident
25-26 February 1991



Friendly Fire Incident: RECONSTRUCTION

- By self-report, Bradley crew obtained 3-4 hrs sleep per night over previous 5 days (sleep deprivation)
- Firefight ensued during early morning hours (circadian rhythm of mental operations)
- Crew able to put cross-hairs on target and fire rounds accurately down-range (simple, well-learned task)
- Crew lost battlefield orientation; could not distinguish friend from foe (complex mental operation) “If it is in front of us, it dies”

Military Effectiveness is Person-Critical

- The person is critical to military effectiveness
- The person must make the correct decision or the system fails
- Military Effectiveness: the person must make the correct decision within a certain, limited time or the system fails

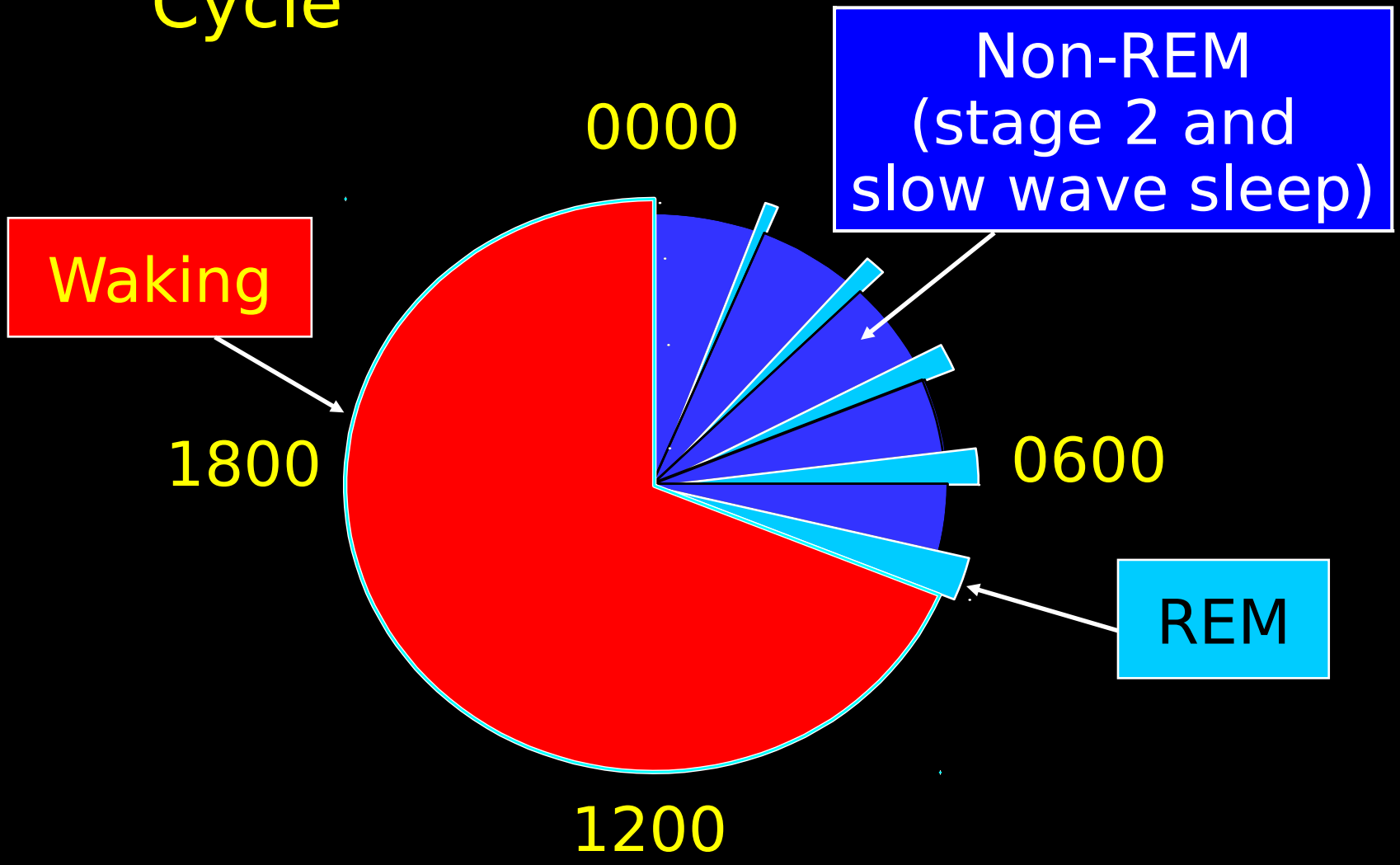
Factors Affecting Military Effectiveness (Individual and Unit Levels)

- Battle intensity / type
- Combat experience, training, and fitness
- Morale, leadership, cohesion, and unit ethical climate
- Personal and family factors
- Physiological factors:
  - Load
  - Hydration
  - Nutrition
  - **Sleep**

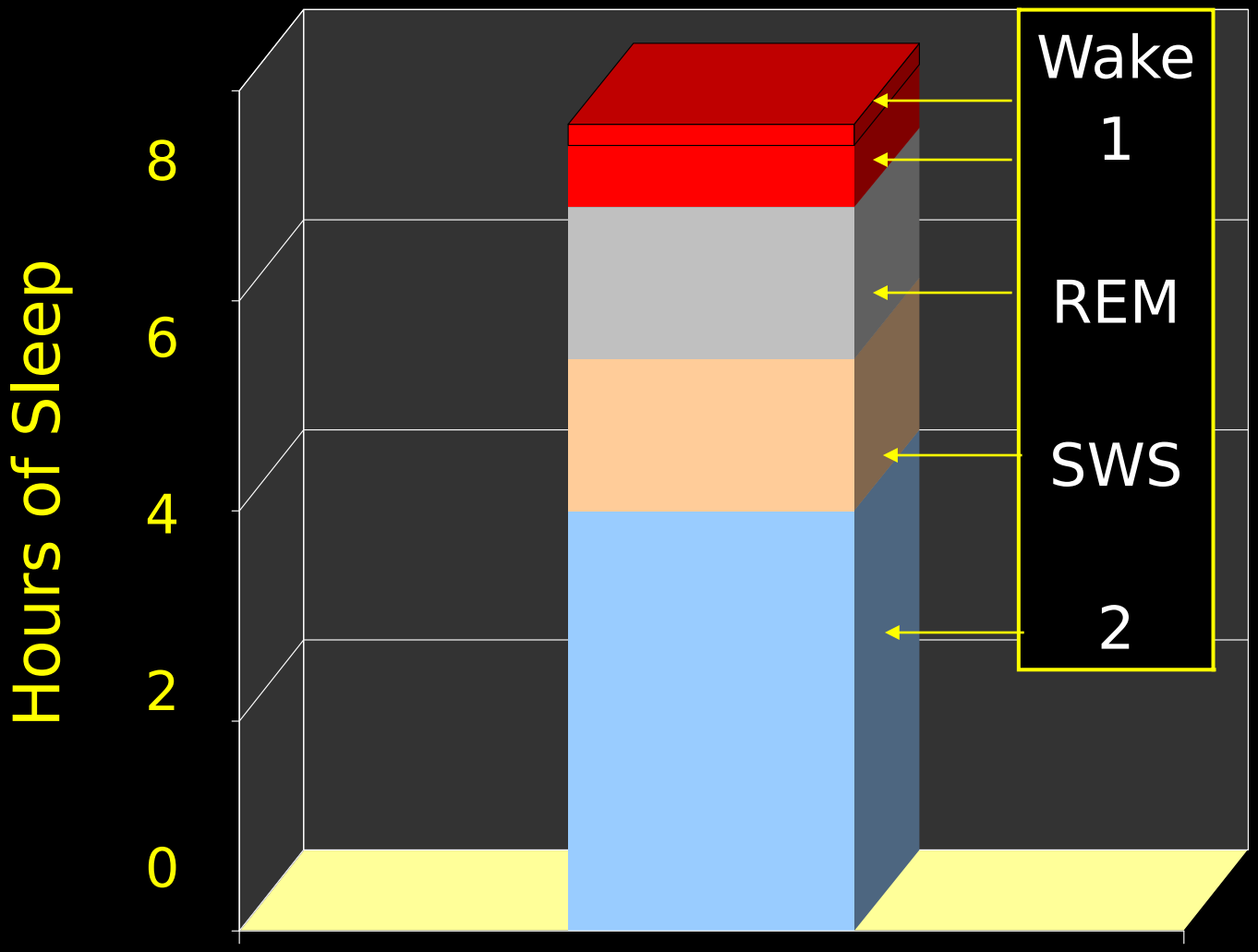
Sleep:

The Basics

The 24-Hour Sleep/Wake Cycle



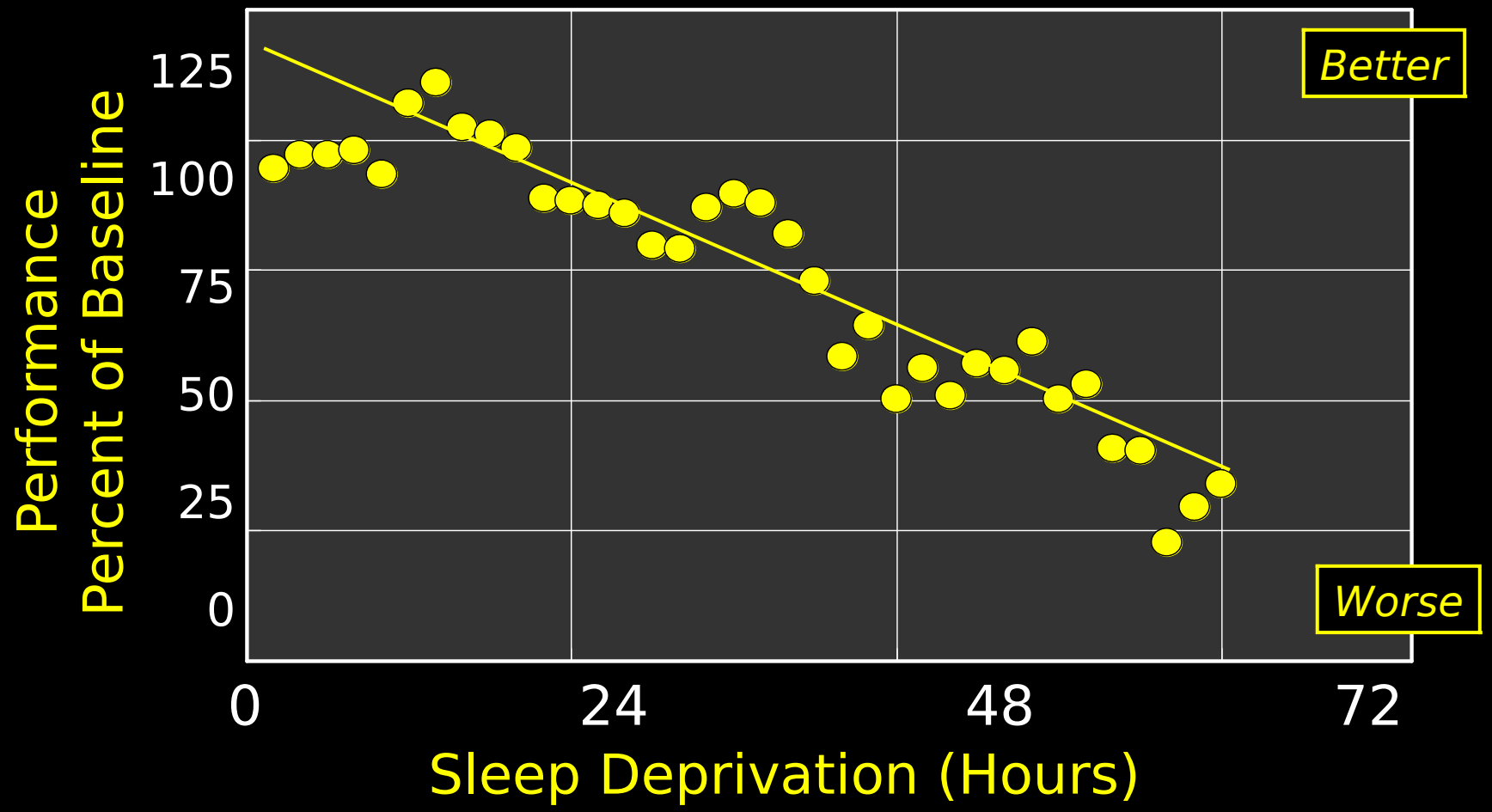
Sleep Stage Distribution
Nighttime Sleep



How long can we get by with no sleep?

Effect of Total Sleep Deprivation on Mental Operations

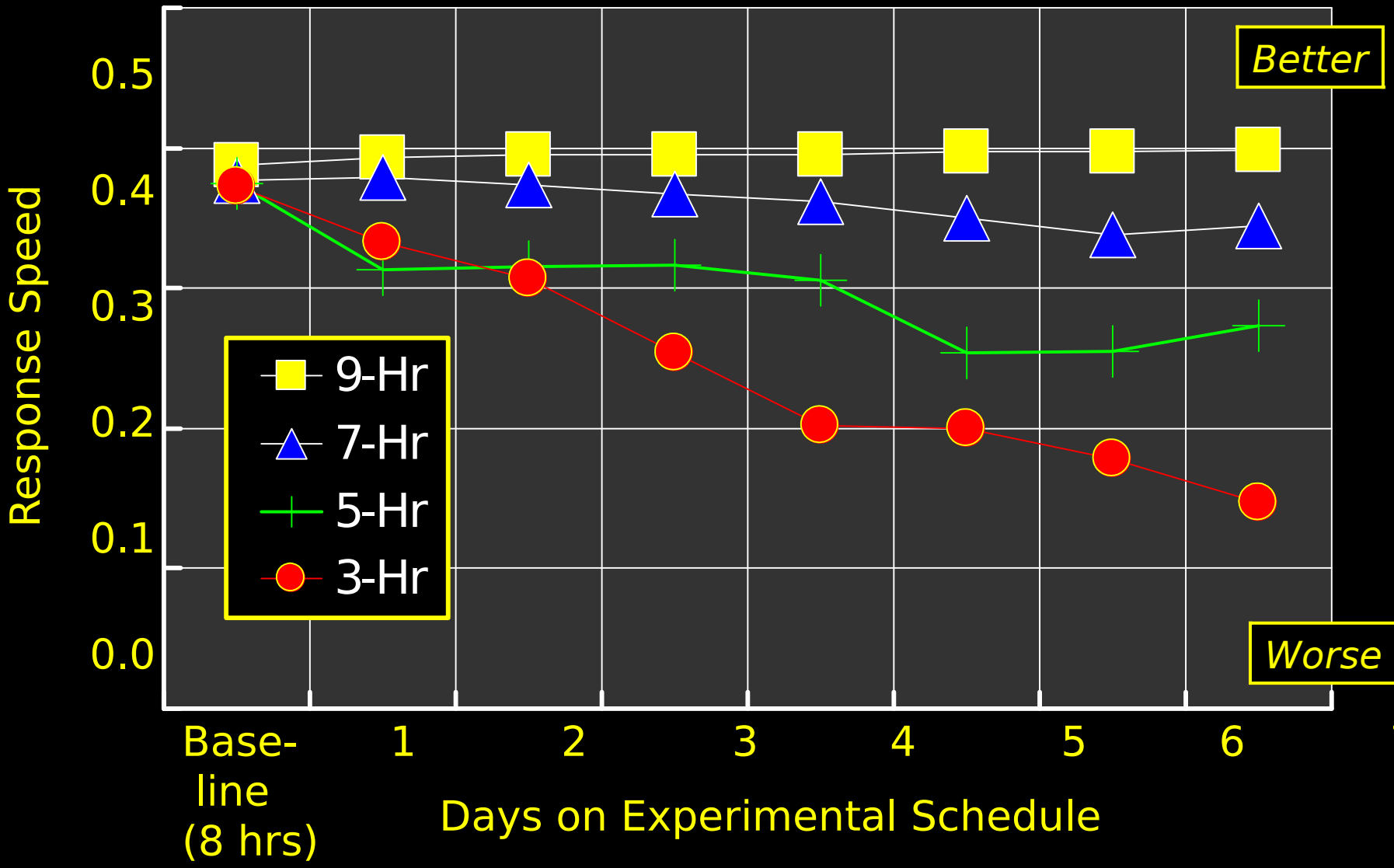
72 Hours of Total Sleep Deprivation: Effect on Complex Mental Operations



Can we get by with less than
8 hours of sleep?

Effect of Restricting Sleep Time
on Mental Operations

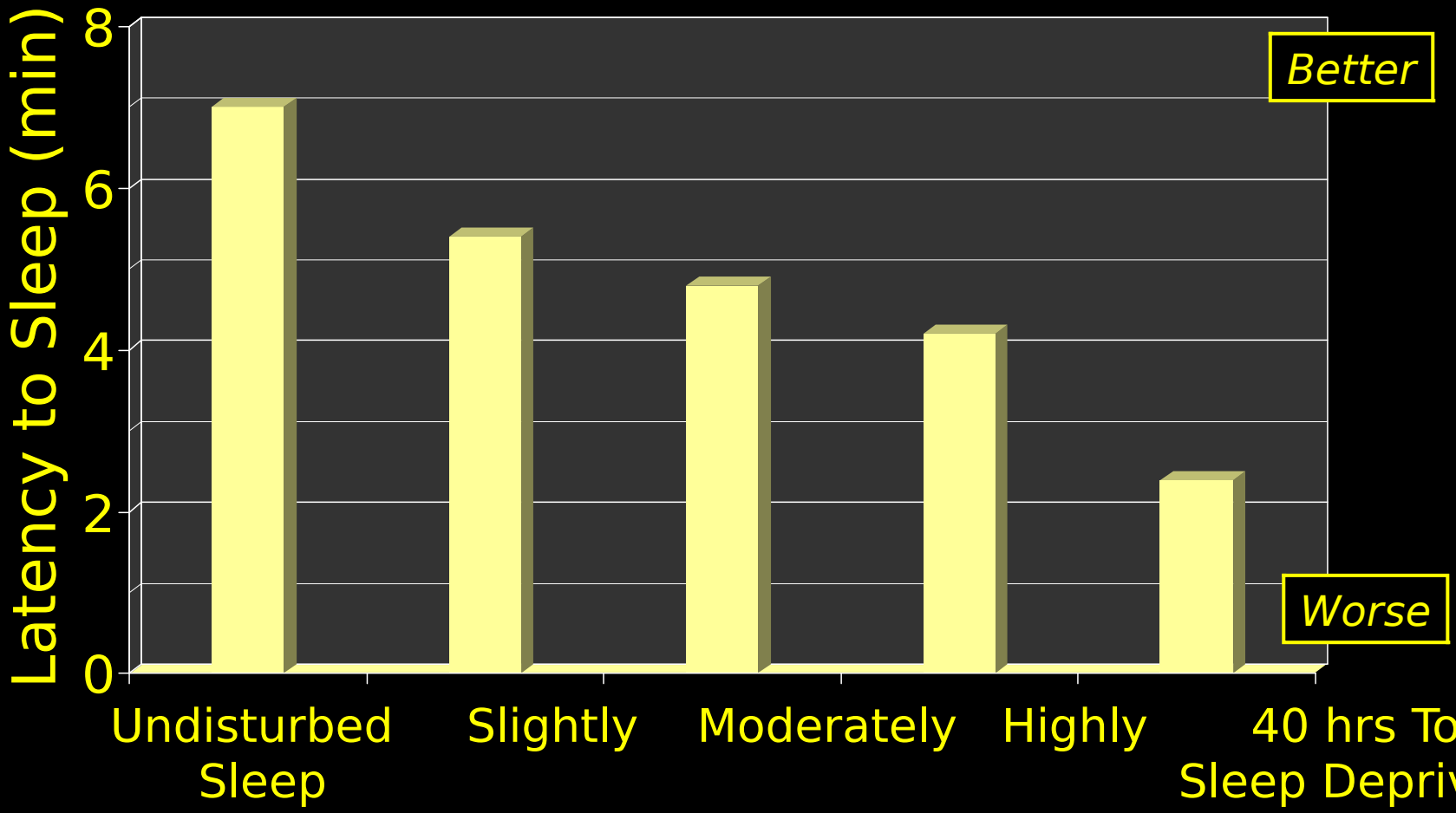
Restricting Sleep: Effects on Vigilance



What happens if sleep is disturbed?

Effect of Disrupting / Fragmenting Sleep on Mental Operations

Disrupting Sleep Impairs Alertness



(adapted from Levine et al., 1987)

Sleep and Sleep Deprivation: SUMMARY

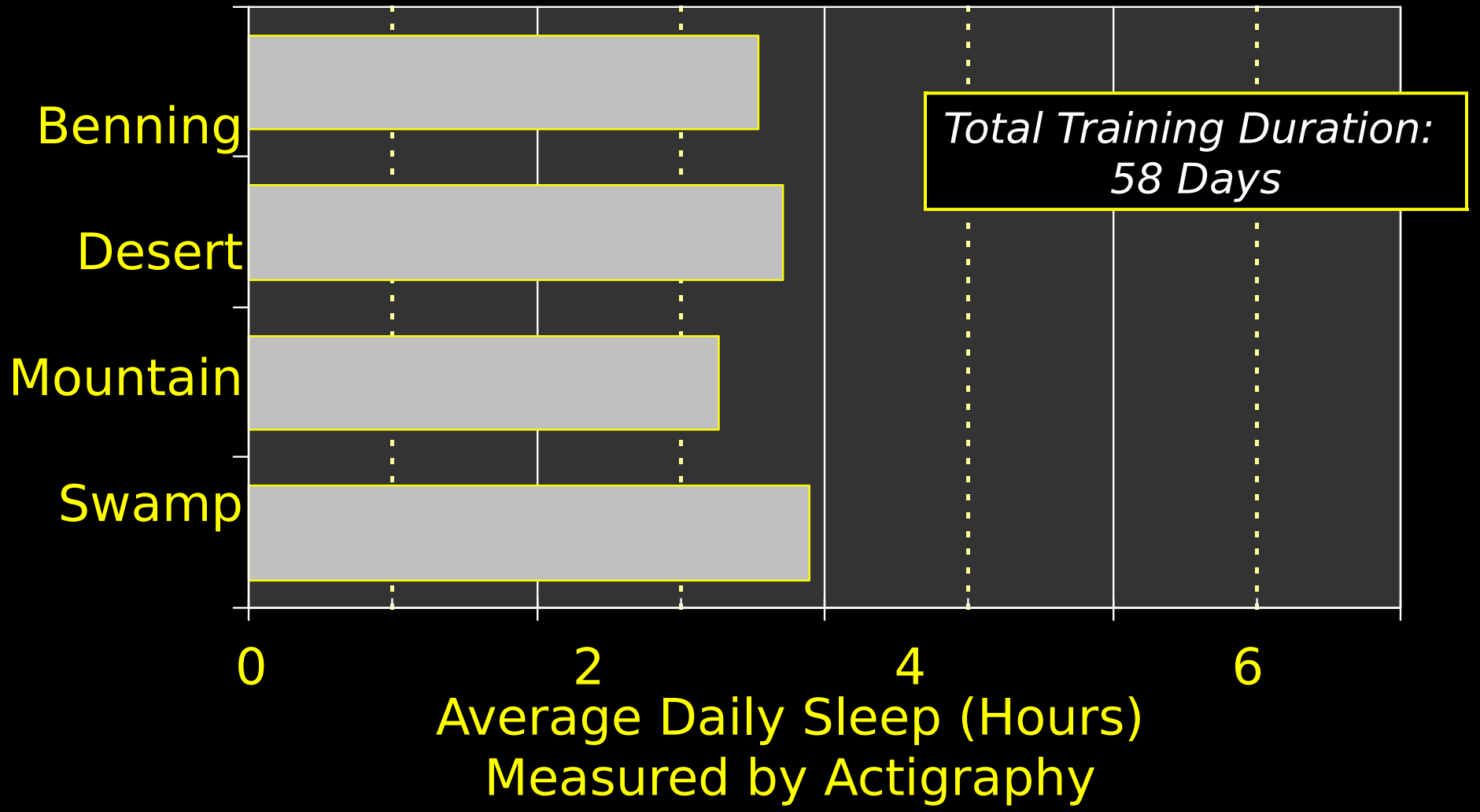
- Sleep deprivation exerts 2 main effects:
  - Makes one more susceptible to falling asleep in a boring or non-stimulating environment
  - Directly impairs higher order mental operations (even in a stimulating environment)

- A state of “sleep deprivation” is induced whenever recuperative sleep time is reduced:
  - Total sleep deprivation
  - Partial sleep deprivation / Restricted sleep
  - Disrupted or Fragmented Sleep

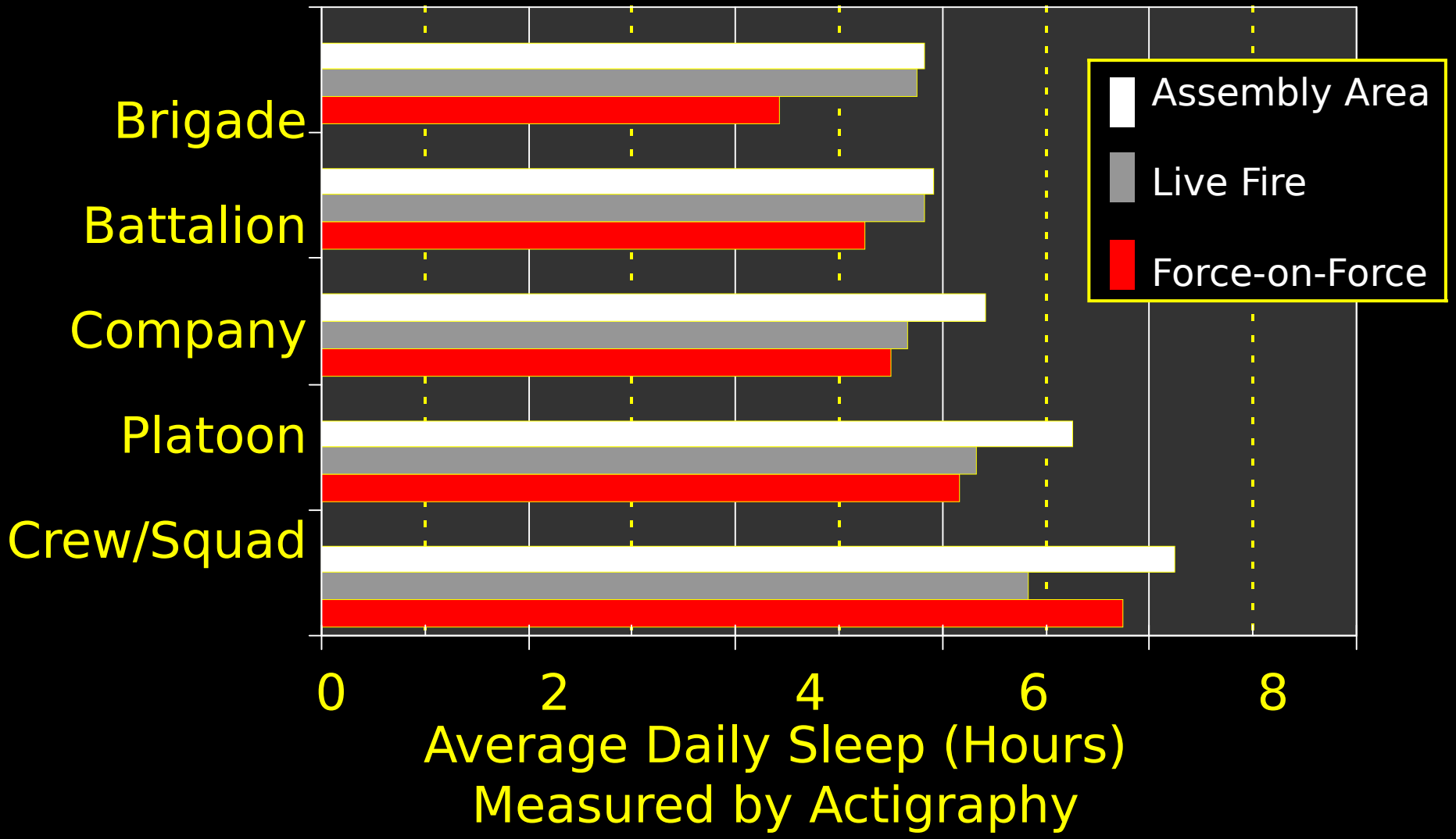
When sleep deprived,
we are poor judges of
our own performance.

How Much Sleep is the U.S. Military Getting?

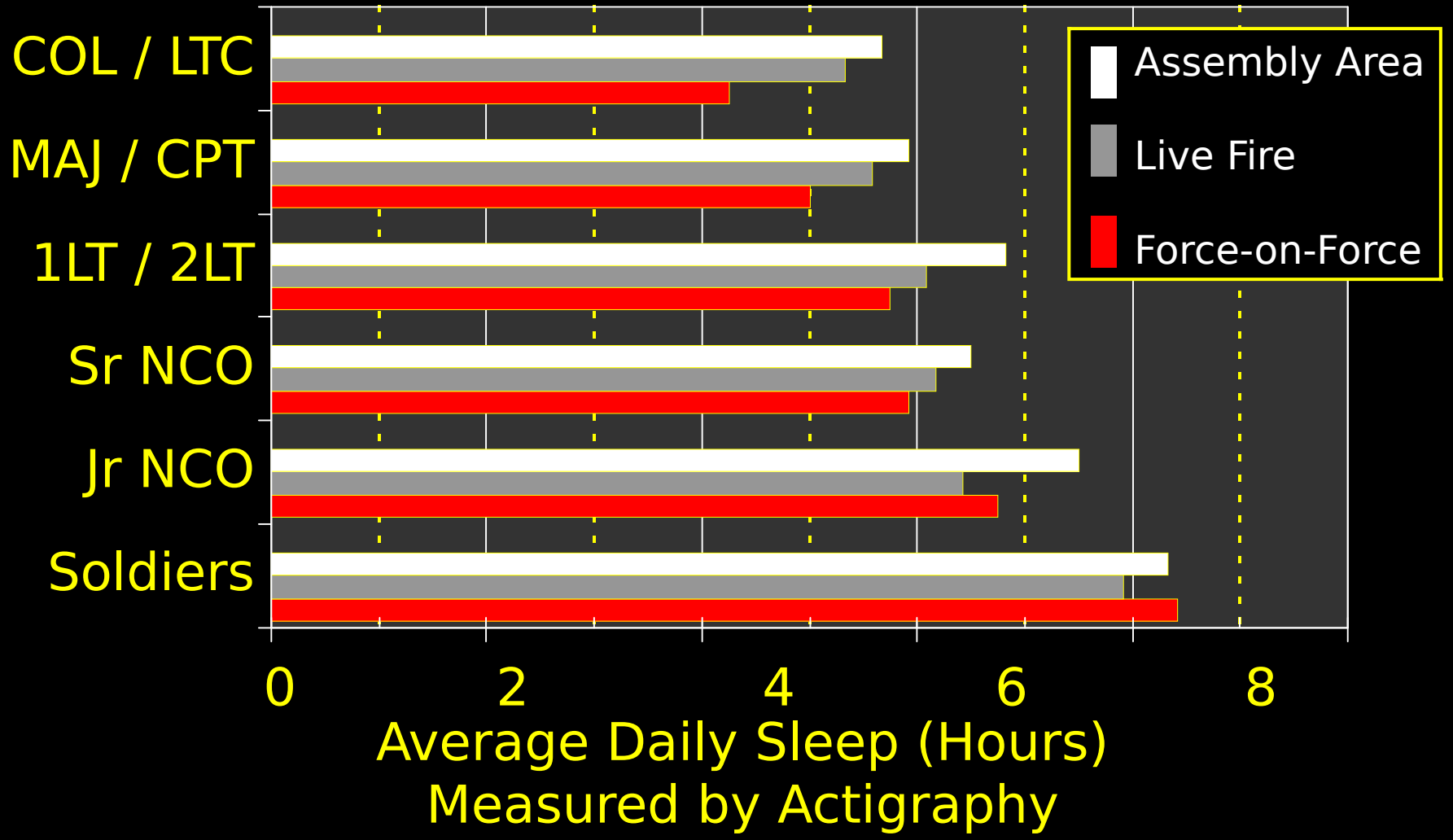
U.S. Army Ranger School:
AVERAGE DAILY SLEEP DURATION



National Training Center:
AVERAGE DAILY SLEEP DURATION



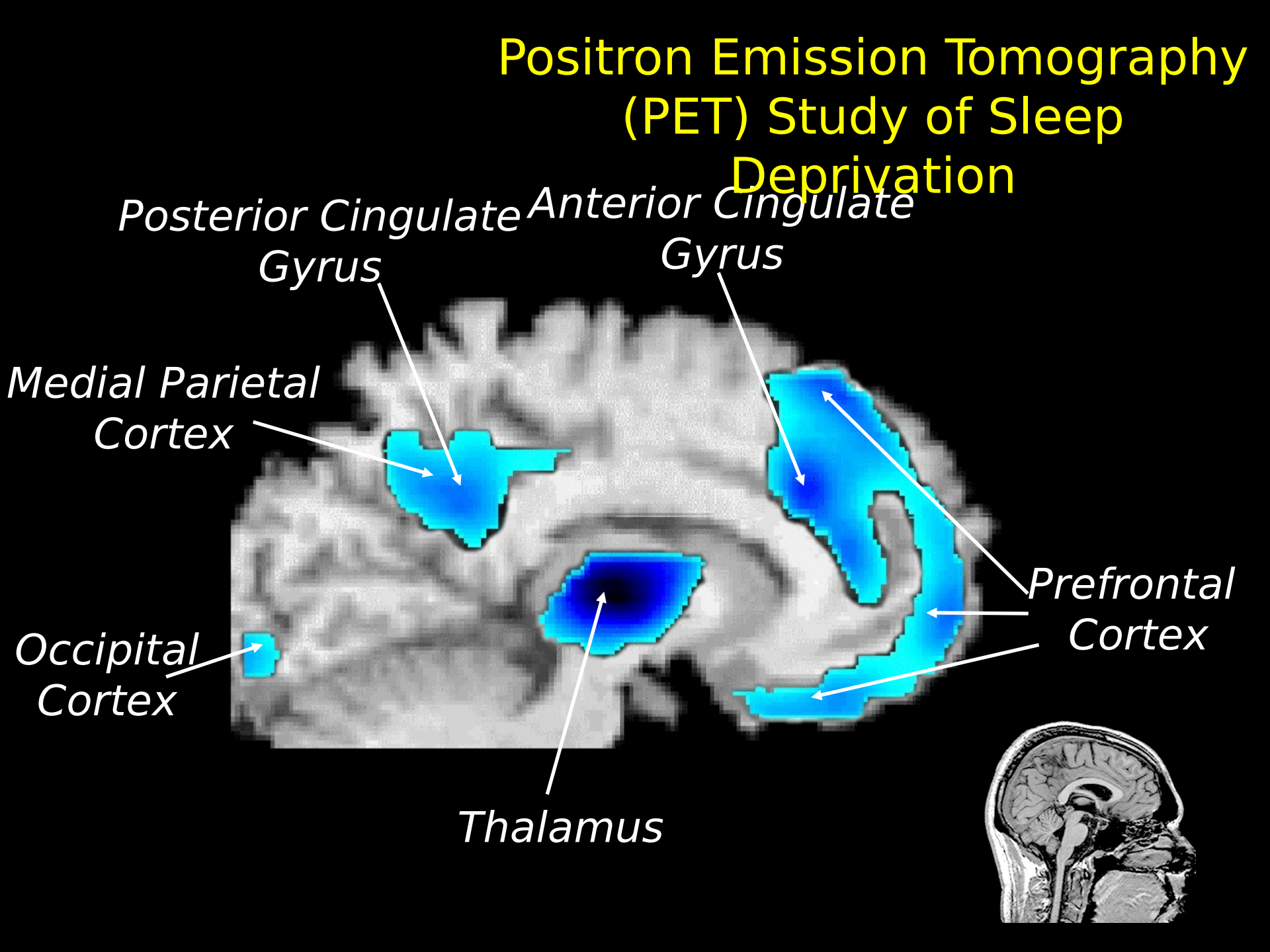
National Training Center:
AVERAGE DAILY SLEEP DURATION
by Rank



Sleep Deprivation:

Neurobiological Changes Underlie Impairments in Mental Operations

Positron Emission Tomography (PET) Study of Sleep Deprivation



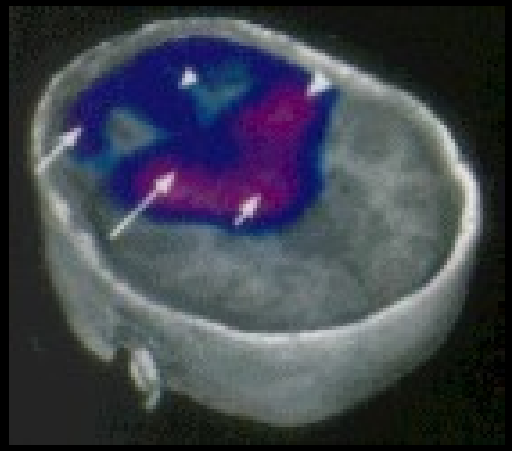
Mental Operations Mediated by these Brain Regions:

- Ability to maintain wakefulness in a boring or non-stimulating environment:
  - Alertness
  - Vigilance
- Higher order mental operations:
  - Situational / battlefield awareness
  - Adaptability, mental agility, judgment
  - Initiative
  - Anticipation, planning

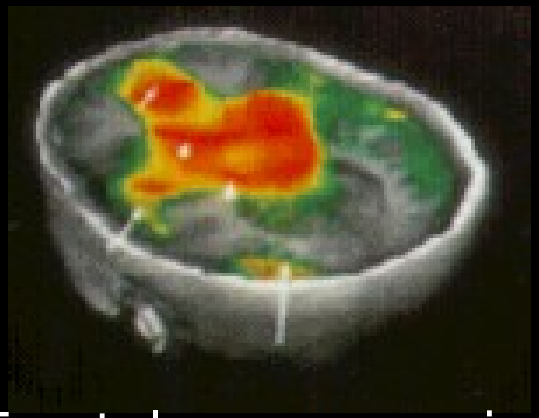
Sleep:

Neurobiological Changes Underlie Restoration of Mental Operations

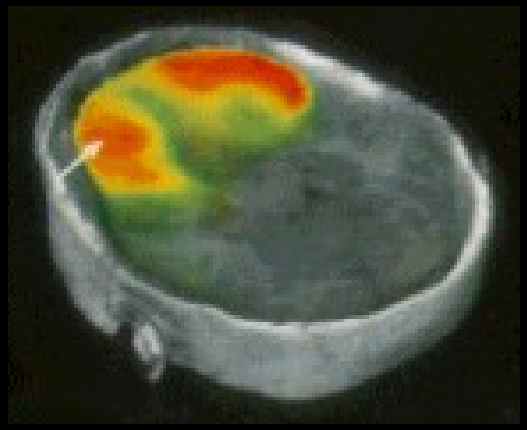
Positron Emission Tomography (PET) Study of Sleep



Frontal areas are deactivated during Slow Wave Sleep



Frontal areas remain deactivated during REM



Frontal areas are re-activated only after awakening

Neurobiological Changes During Sleep Deprivation & Recovery Sleep: SUMMARY

- Brain regions most affected by sleep deprivation = same regions most deactivated during sleep

- **Primary Function of Sleep:** restore / sustain brain regions that mediate:

  - the ability to maintain wakefulness in non-stimulating environments

  - higher order mental operations

How much sleep do you need to perform YOUR job?

Sleep Deprivation:

- Increases likelihood of falling asleep under these conditions:

  - Boring
  - Repetitive
  - Long-duration
  - Infrequent events
  - Lack of other stimulation (mental or physical)

- Directly impairs mental performance under these conditions (even in a stimulating environment):

  - Novel task (not well learned)
  - Complex task
  - Tasks requiring novel solutions

Example: Why does sentry duty require near-optimal amounts of sleep?

- Sentry duty appears to be a simple task, easily learned.
- Increased likelihood of falling asleep: boring, non-stimulating environment, long intervals between relevant events
- Direct impairment of mental operations: appreciating relevancy of events and formulating the appropriate response

SUMMARY

- Sleep deprivation increases likelihood of sleep in a boring or non-stimulating environment
- Sleep deprivation also directly impairs mental operations
- 8 hours sleep per day is optimal
- Anything less than 8 hrs results in a performance penalty if the task is boring or non-stimulating, or requires higher order mental operations

Circadian Desynchrony
(Jet Lag)

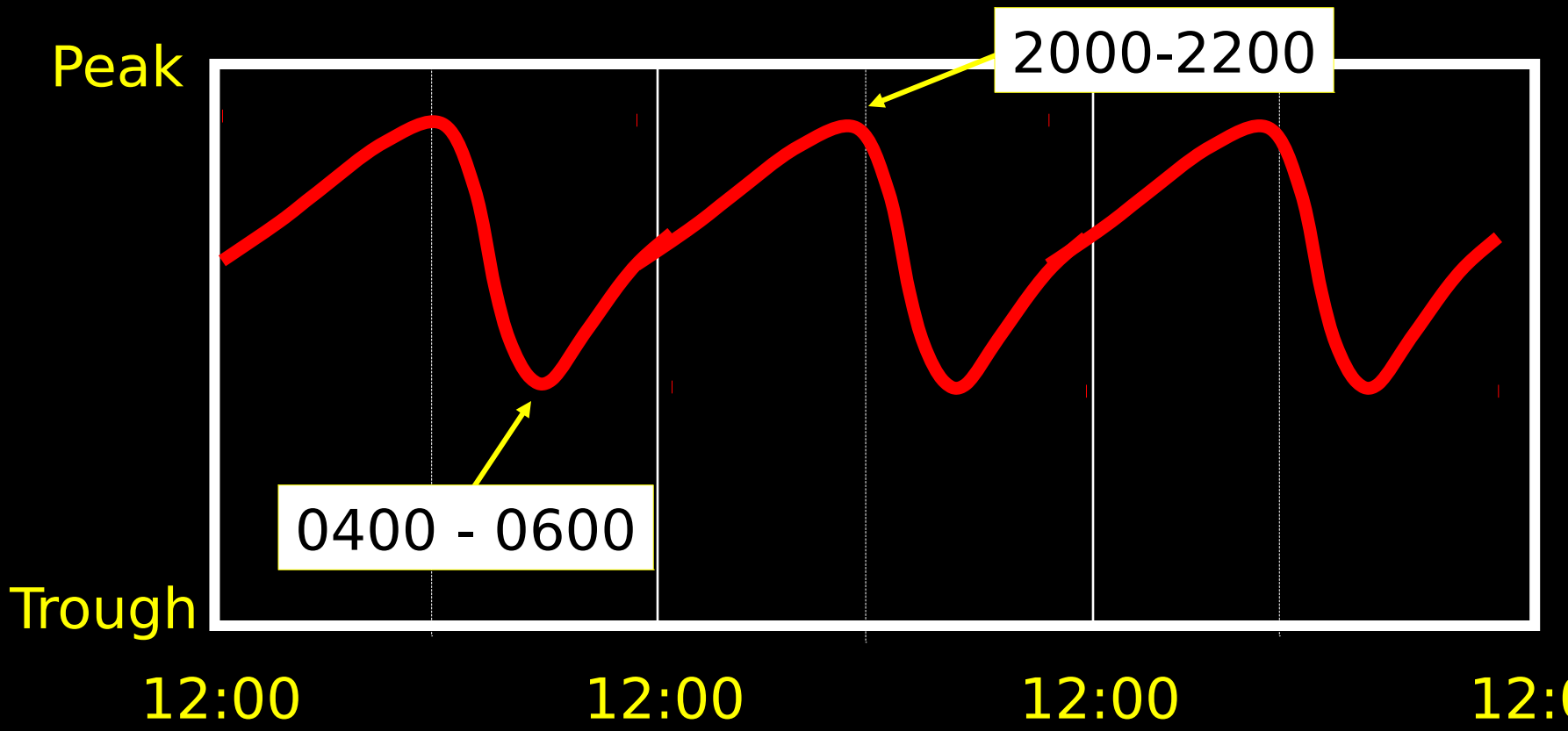
or

Your Body has been deployed to Germany;
Meanwhile, Your Brain is still in the U.S.

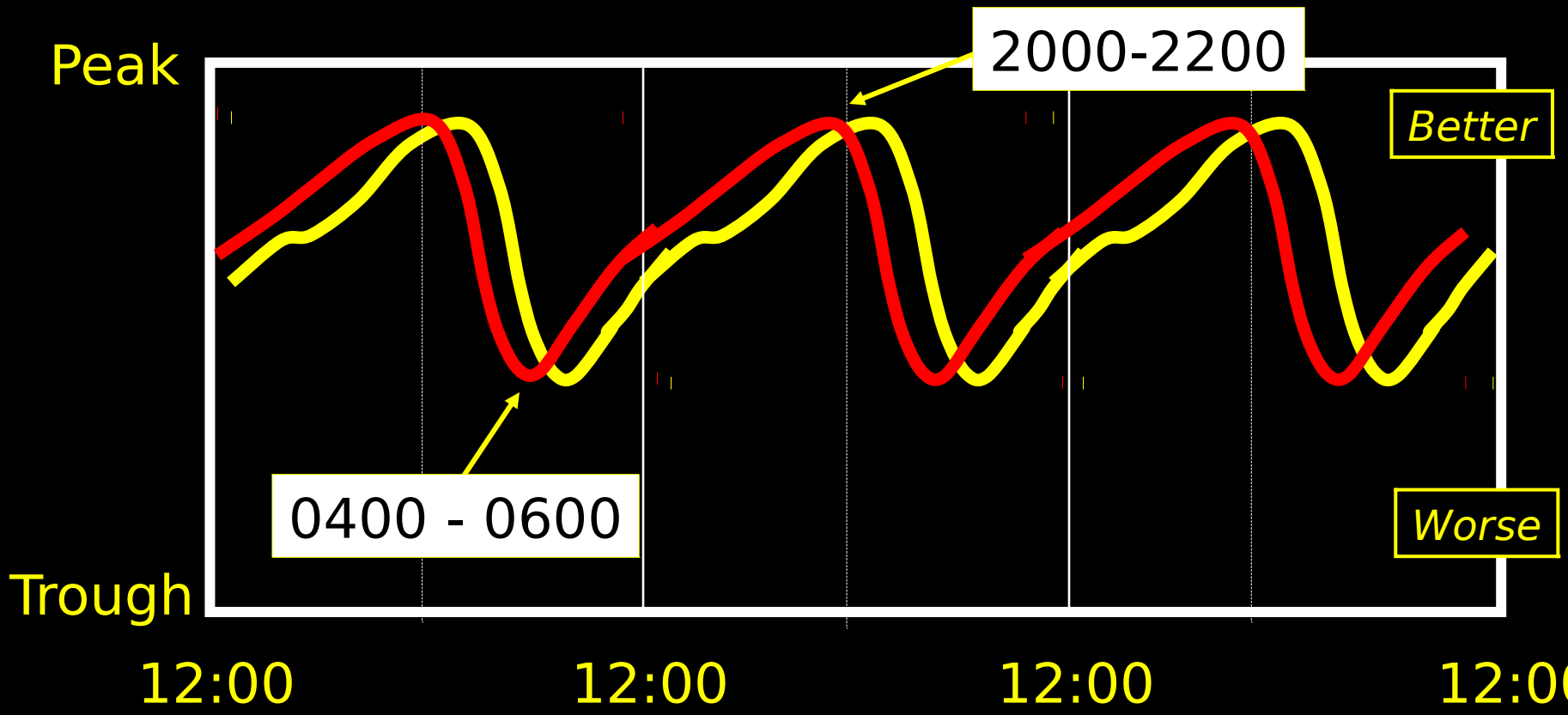
Circadian Rhythmicity:

The Basics

Daily 24-Hour or “Circadian” Rhythms:
Body Temperature

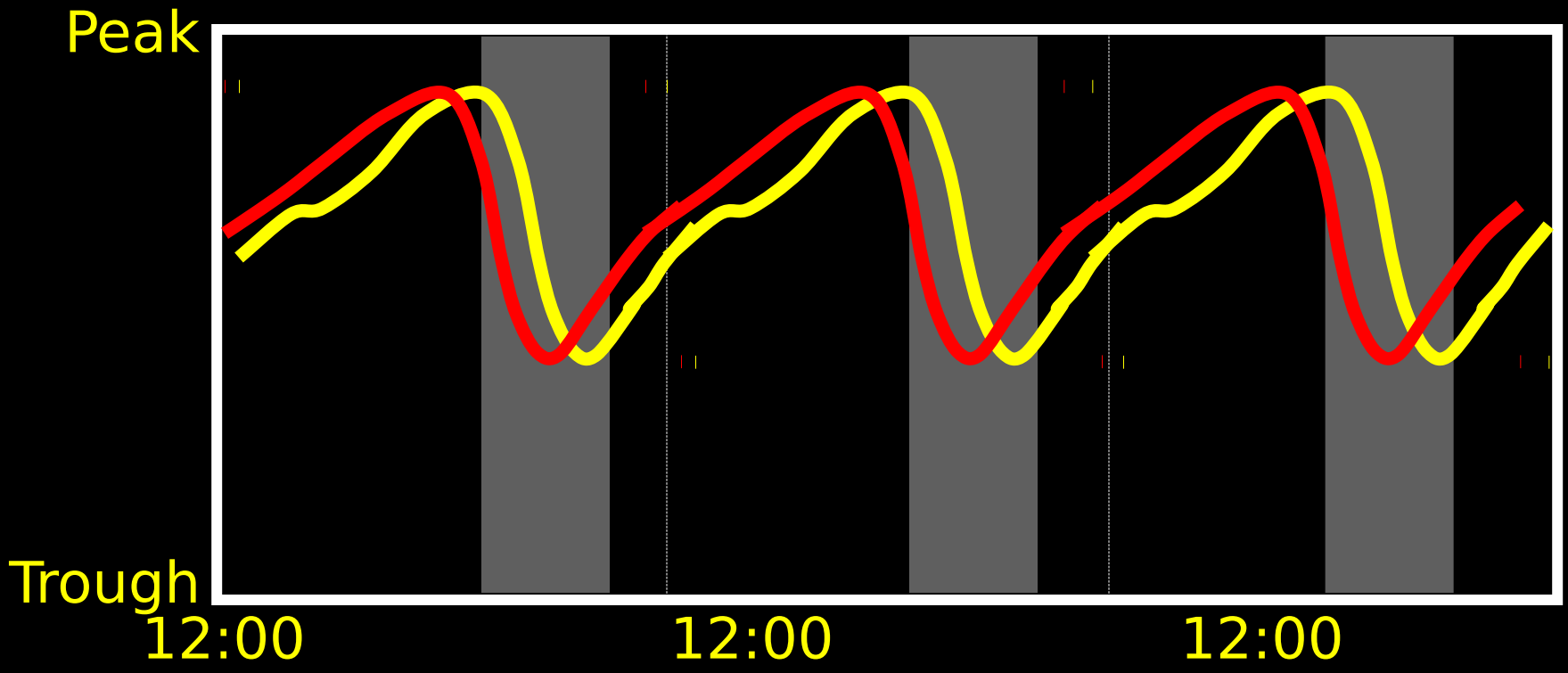


Circadian Rhythms:
Body Temperature • Mental Operations

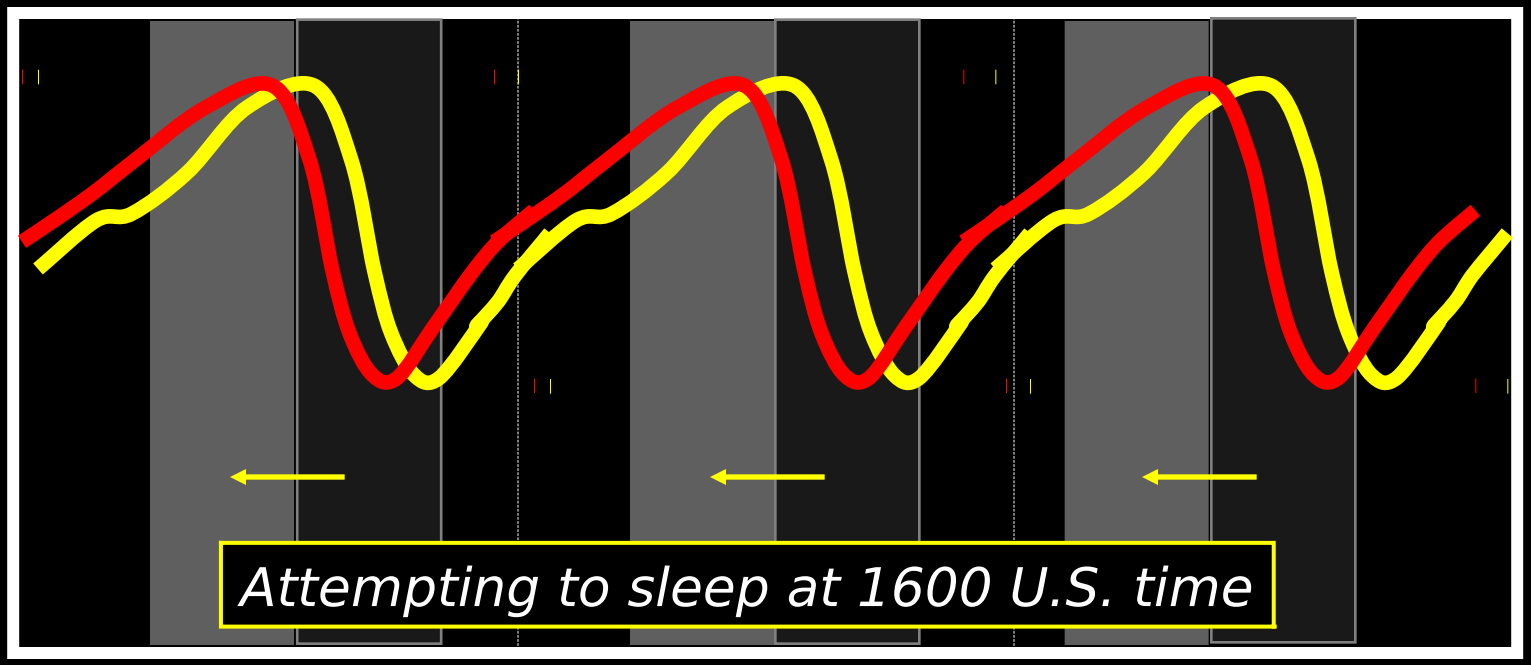


Relationships:

SLEEP • Body Temperature • Mental Operations



8-HOUR TIME ZONE ADVANCE
(U.S. to Europe)



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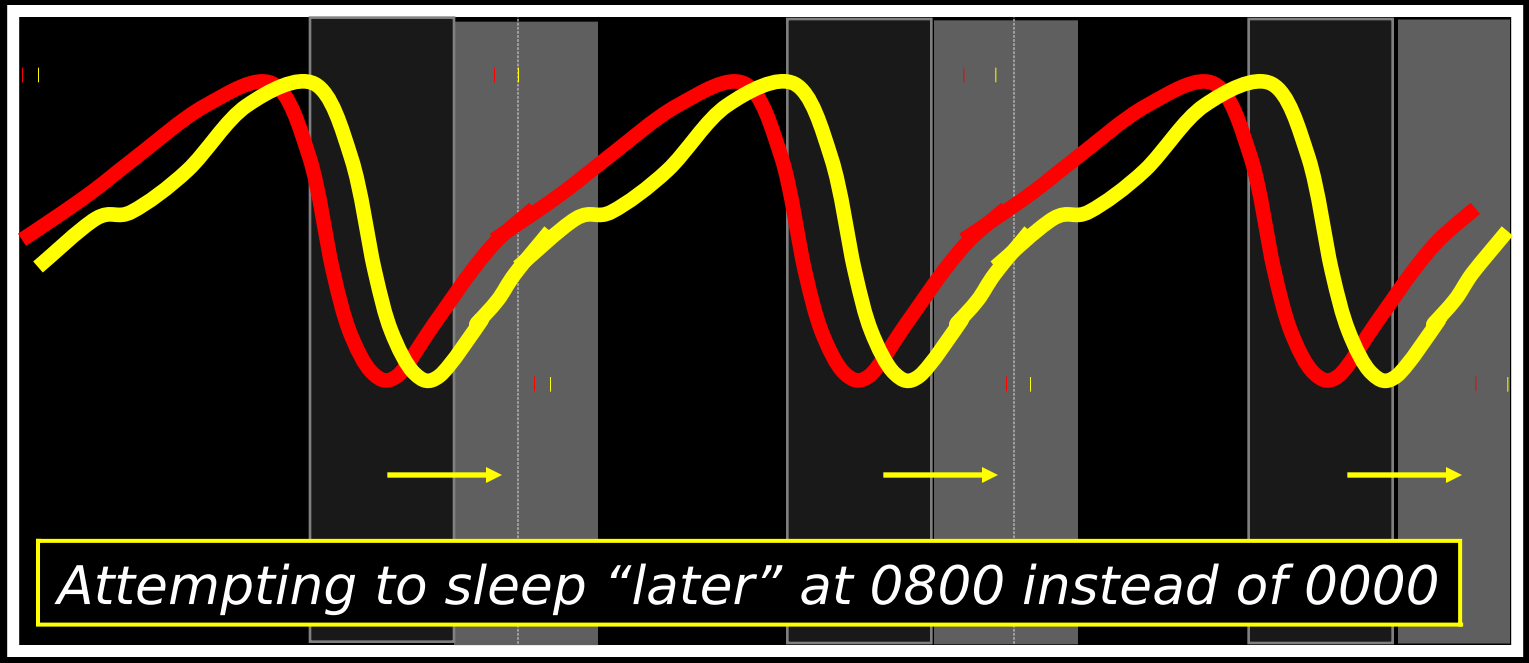
8-HOUR TIME ZONE DELAY
(U.S. to somewhere in the Pacific)



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Desynchronosis:
Subjective Components

- Impaired mood, increased irritability
- Reports of insomnia
- Feelings of being sleepy, tired, fatigued
- Reports of feeling nausea, G-I distress, headache, dizziness

Desynchronosis:
Objective Components

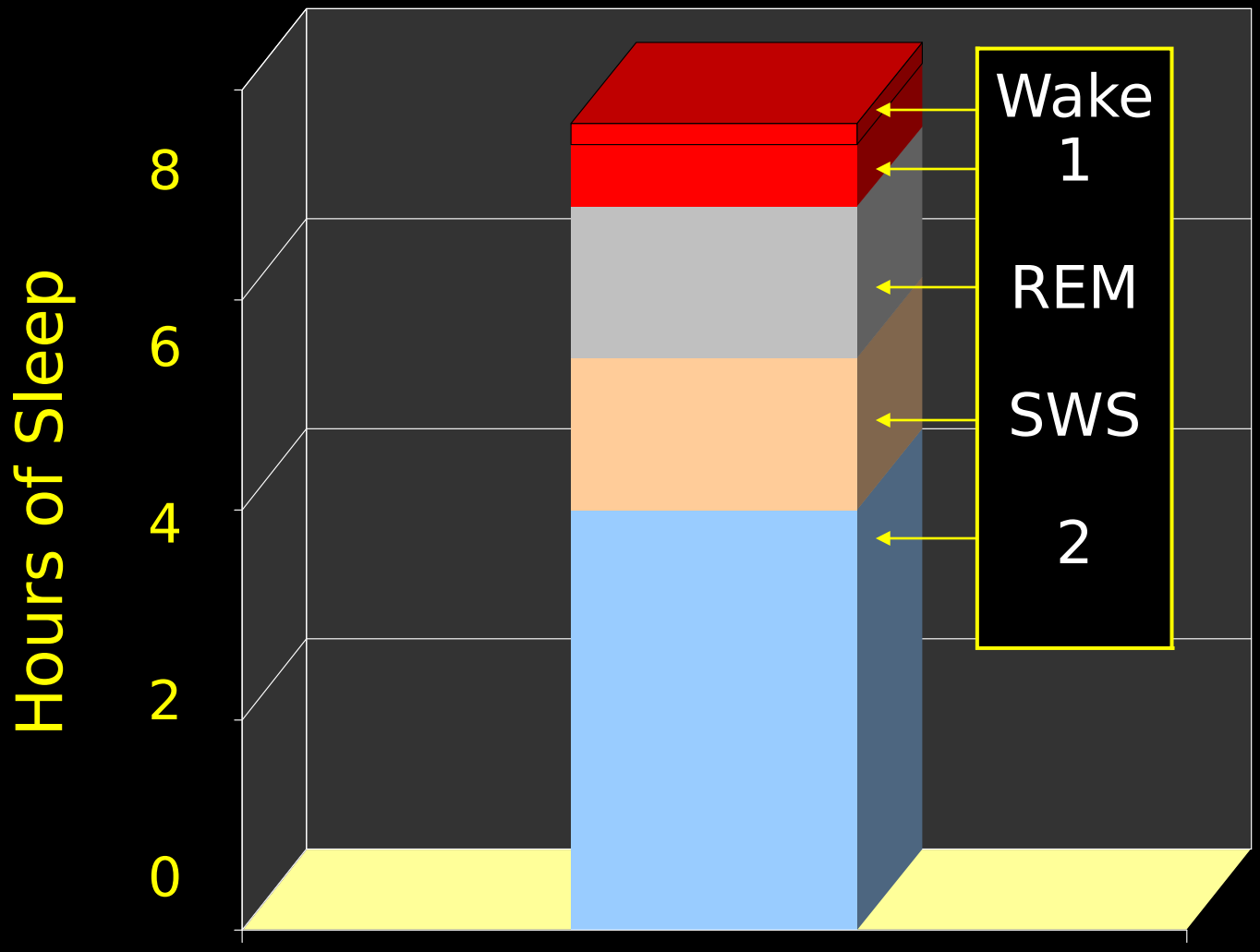
- Sleep is disrupted - sleep duration decreases (even with sufficient time available to sleep)
- Mental operations are impaired
- Increased levels of “stress” hormones
- Physical performance not impaired

Desynchronosis:
VARIABLES AFFECTING SEVERITY

- Age
- Gender = no effect
- Personality variables = no effect

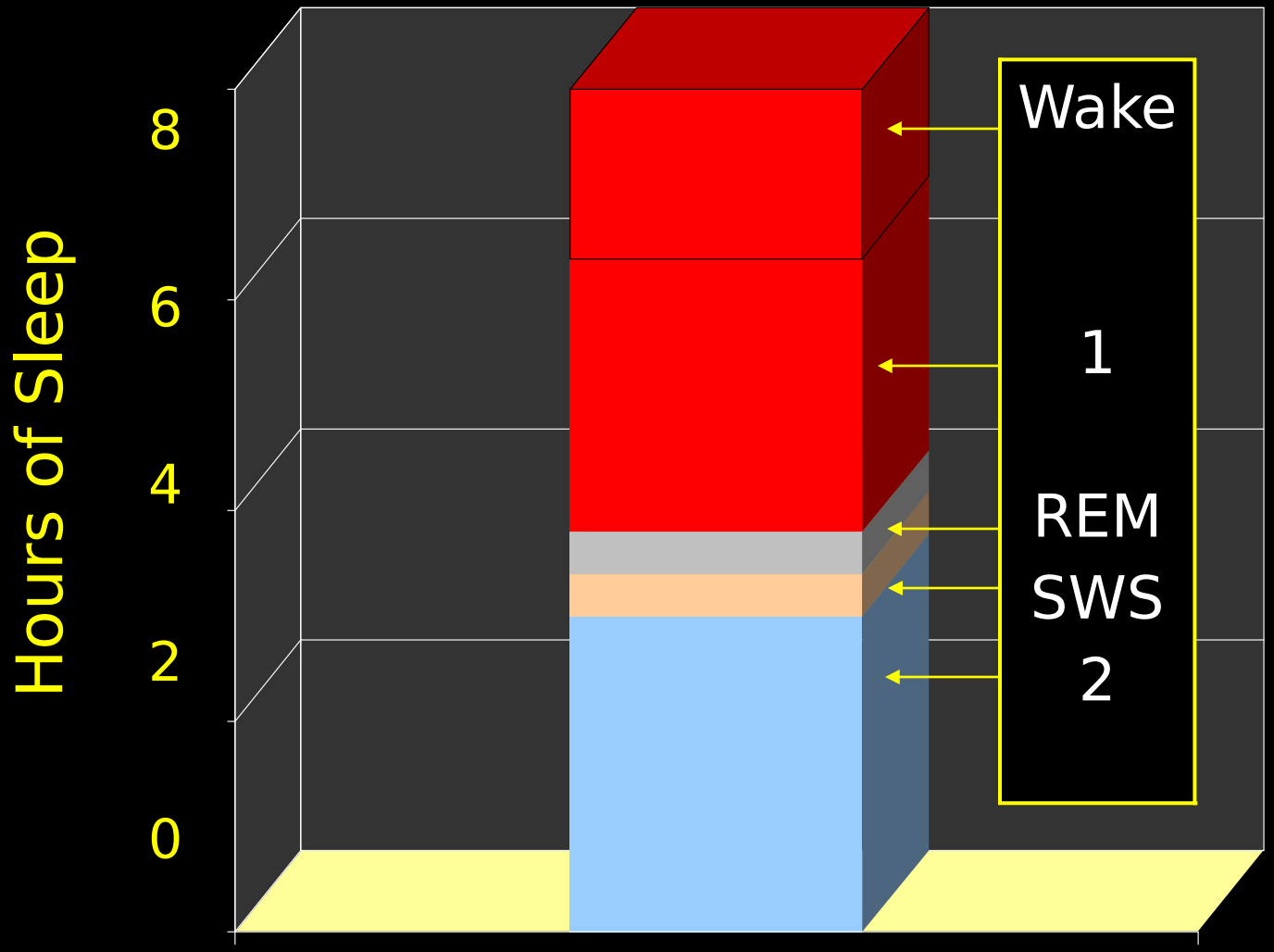
Effect of time zone change on SLEEP

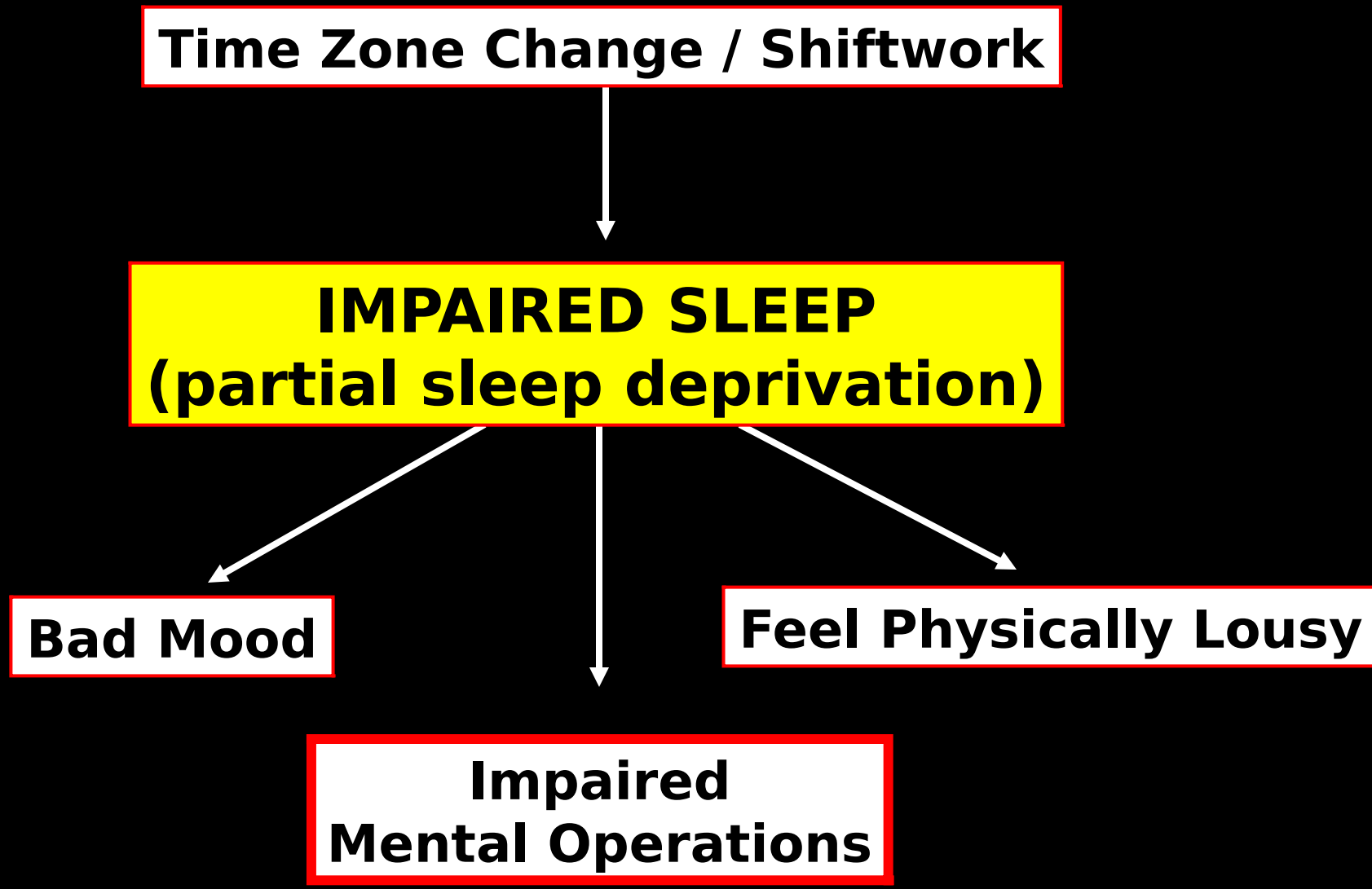
Typical Sleep Stage Distribution



Sleep AFTER Time Zone Change

More Non-Recuperative Stages




Time Zone Change / Shiftwork
IMPAIRED SLEEP
(partial sleep deprivation)
Bad Mood
Feel Physically Lousy
Impaired
Mental Operations

Most effective approaches for minimizing effects of time zone shifts (jet-lag):

IMPROVE / INCREASE SLEEP

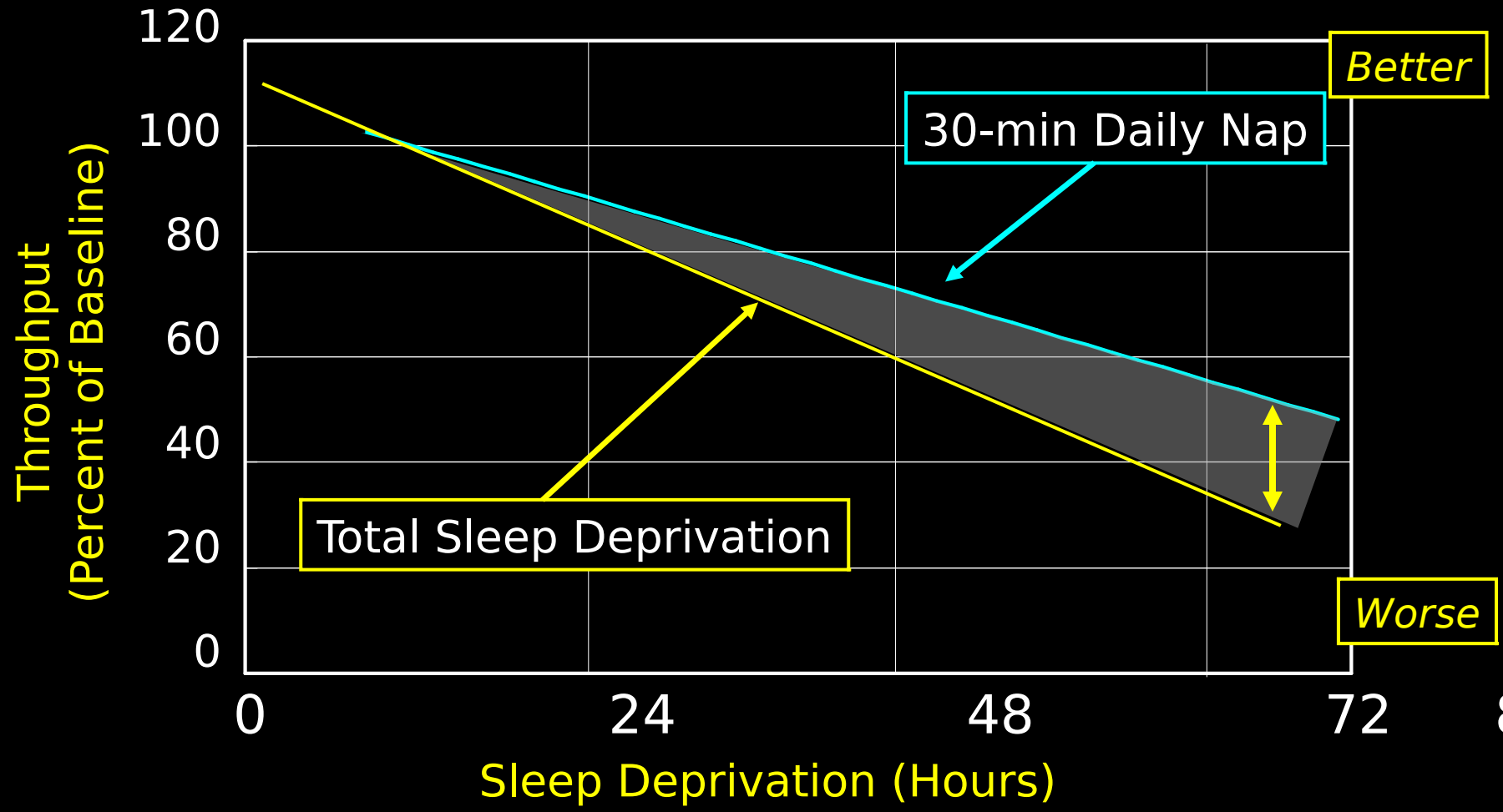
Insert Mental Health Break HERE

Strategies to Improve Sleep

Strategies to Improve Sleep:

What about Naps?

Recuperative Value of Sleep: Daily 30-min "Nap"



Adapted from Thomas et

Naps:
SUMMARY and RECOMMENDATION

- Even short bouts of sleep will improve performance
- KEY: To be useful, a nap must consist of sleep (stage 2, SWS, or REM)
- As long as they contain ***equal sleep amounts***, several short sleep bouts = one long sleep bout
- Dosing or resting - does not restore/sustain mental operations but may make you feel better
- Recommendation: sleep as often and as long as you can to reach the daily optimum 8 hours

Improving the Sleep Environment: RECOMMENDATIONS

- When possible, time sleep periods for certain times of the day (early morning and late afternoon)
- Sleep in the quietest, darkest place available (center of activities is NOT sleep-conducive)
- Ear plugs to block ambient noise
- Sleep masks to block ambient light
- “Relaxation tapes” do not objectively improve sleep (may even disrupt sleep), but may help person feel relaxed

"Self-Help" Interventions to Improve Sleep
What the Person Can Do (But Probably Won't)

- Avoid substances that fragment sleep (increase wake & stage 1); cause partial sleep deprivation:
  - caffeine
  - nicotine
  - alcohol
- Persons unaware that substances objectively impair sleep; hence resistance to give up substances
- Dietary constituents: no objective effects on sleep in normal, healthy individuals

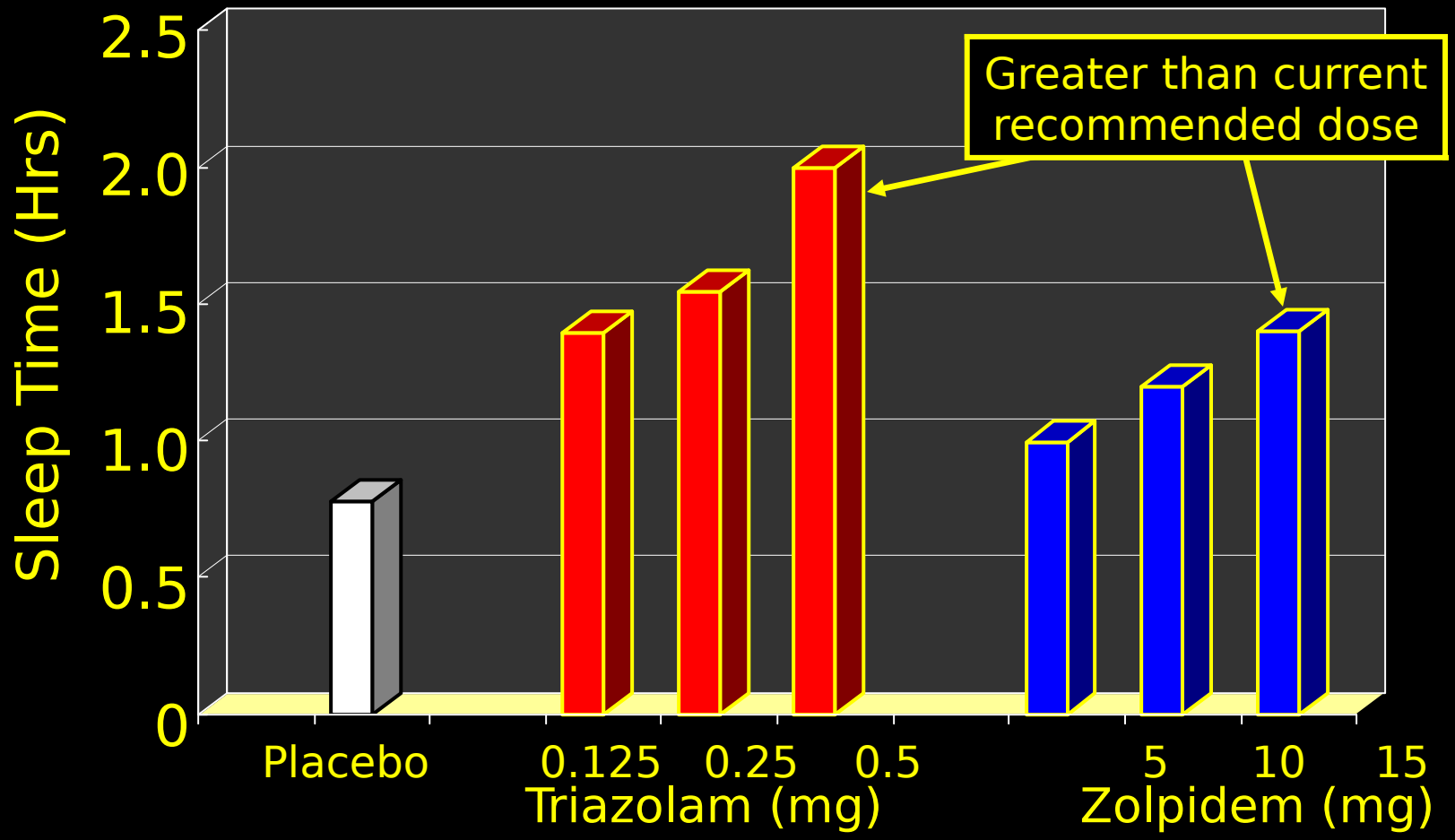
Strategies to Improve Sleep:

Sleep-Inducing Agents

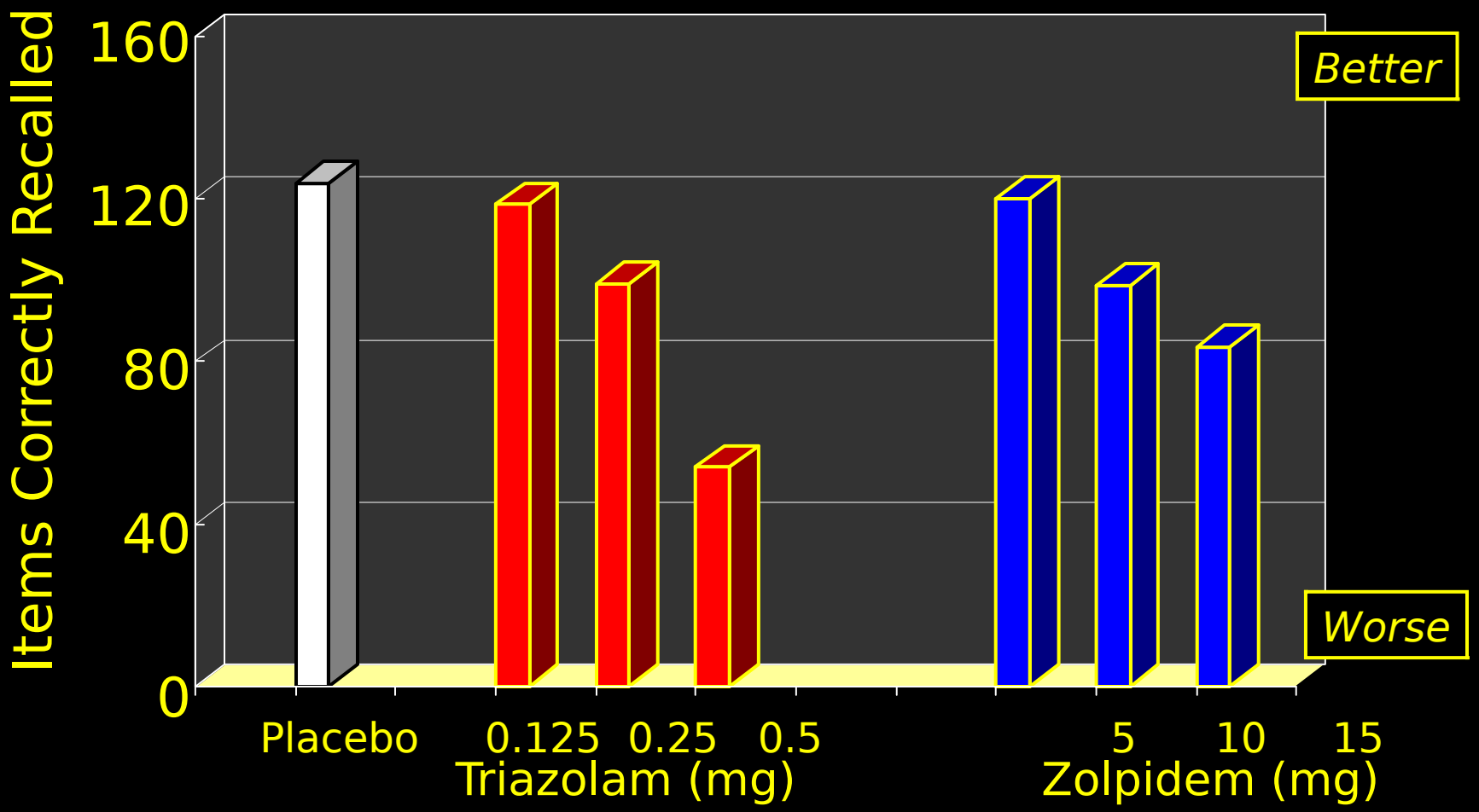
Characteristics of the Ideal Sleep-Inducing Agent

- Increase recuperative sleep time
- Rapid onset of action
- Short duration of action
- No impairment of post-sleep mental operations

Triazolam & Zolpidem:
SLEEP under SIMULATED TROOP TRANSPORT

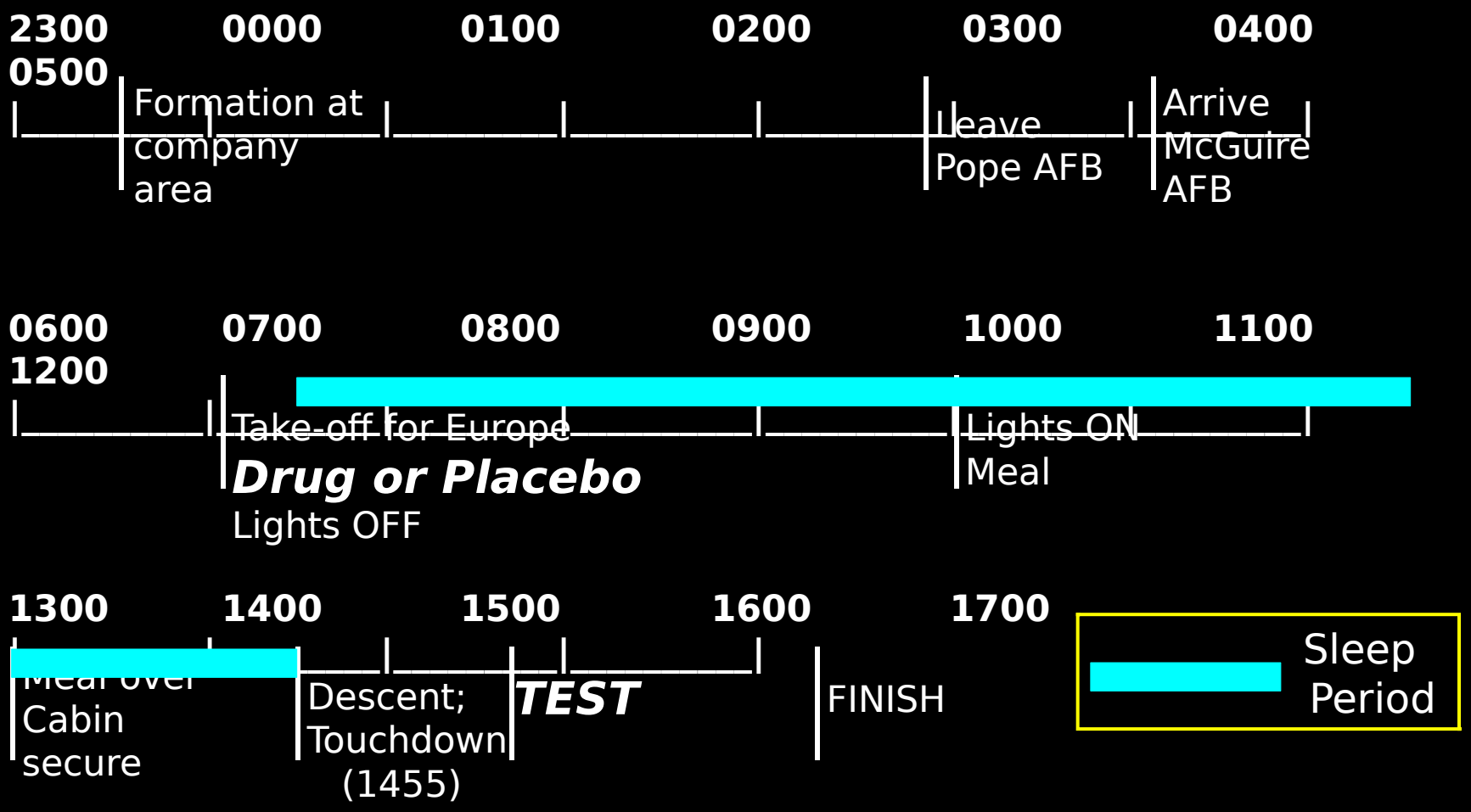


Triazolam & Zolpidem:
MEMORY under WORST-CASE SCENARIO
(PEAK DRUG EFFECT)

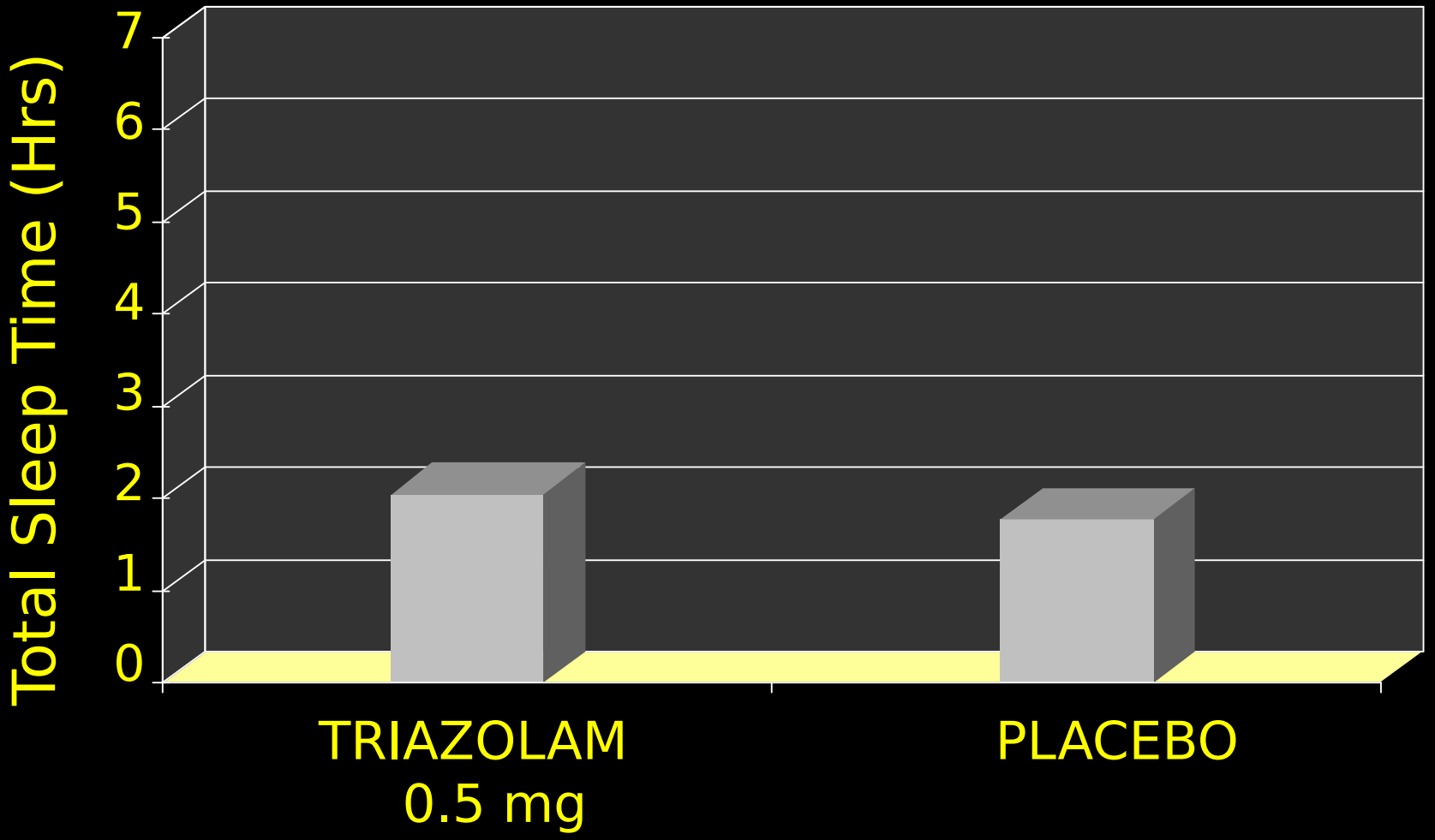


Triazolam:
Use in the Field

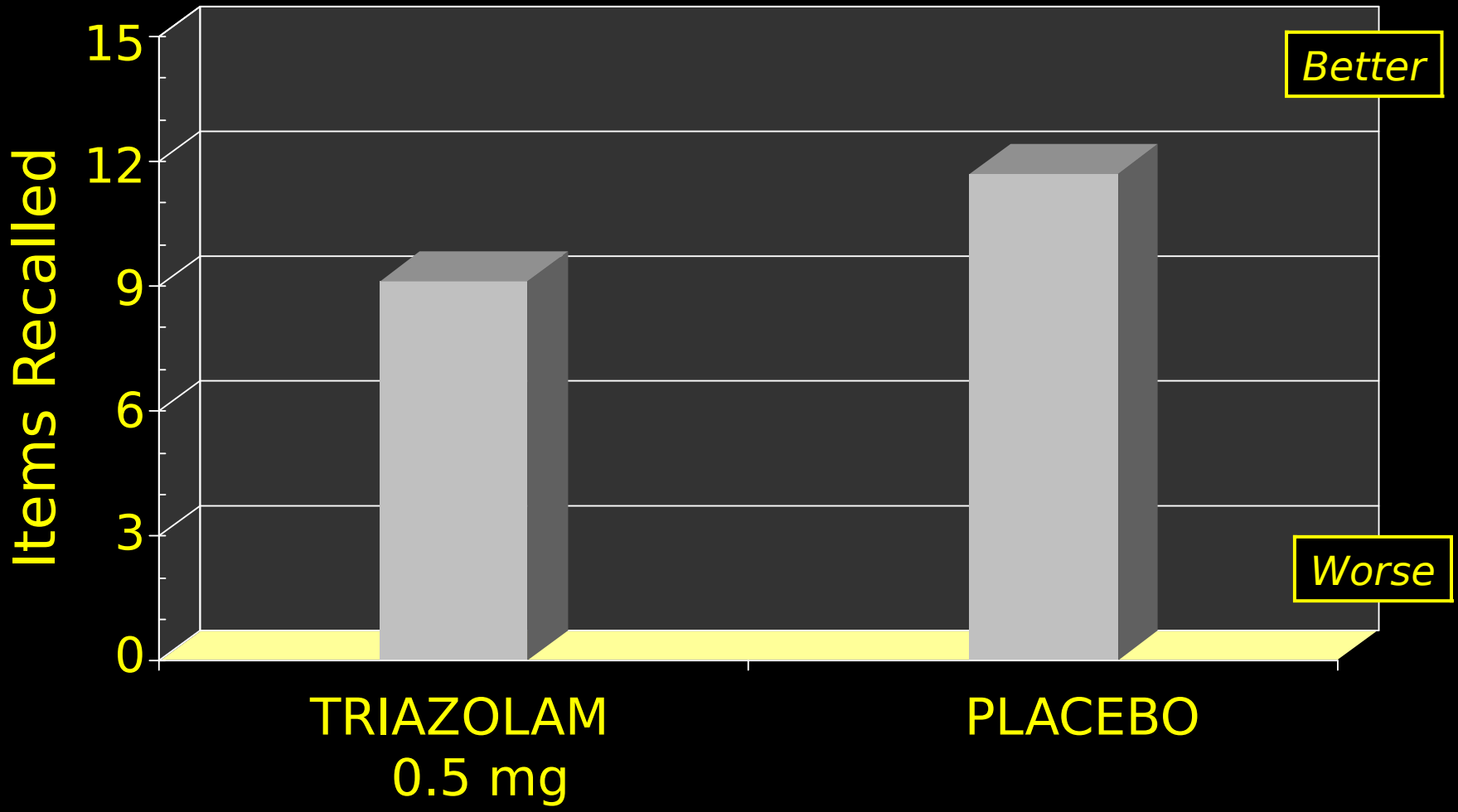
Triazolam 0.5 mg:
DEPLOYMENT of the 18TH AIRBORNE



Triazolam 0.5 mg:
SLEEP DURING DEPLOYMENT



Triazolam 0.5 mg:
MEMORY IMPAIRMENTS
8 Hours Post-Drug



WHY DIDN'T TRIAZOLAM WORK for the 18TH AIRBORNE?

- In-flight meal started 3 hours after drug administration
- Meal service lasted 2.5 hours; disrupted all soldiers the entire time
- Type of disruption differed from lab simulation:
  - Lab = noise, light, uncomfortable chair (could be ignored)
  - Plane = situations requiring a response from the soldier (could not be ignored)

Triazolam:
SLEEP in the FIELD - FT. LEWIS

- 9 Ranger rifle platoons w/ 30 soldiers per platoon
- Environment = sleeping bag, sub-freezing temp, in the open under trees or in unheated barracks; **otherwise no disruptions**
- Triazolam 0.5, 0.25, or placebo
- 4-hour sleep period w/ sleep/wake recorded using actigraph
- Mental performance tested upon awakening, then again 20 hours later (4 and 24 hrs post-drug)

Triazolam-Induced Sleep at Ft. Lewis: RESULTS

- Triazolam 0.5 and 0.25 mg substantially improved sleep in the field
- Triazolam 0.5 mg impaired performance measured immediately upon awakening from the 4-hour sleep period (4 hrs post-dose)
- 24 hours post-dose, triazolam 0.25 mg group showed better performance than placebo group (12% improvement)
- NOTE: triazolam caused some soldiers to fall asleep even before they were zipped into their sleeping bags

Sleep-Inducing Agents: SUMMARY

- At sufficient doses, sleep-inducing agents can improve sleep in the operational environment
- Sleep-inducing doses may impair mental performance
- When sleep-inducing agents are administered, precautions must be taken to ensure that:
  - the sleep period is protected (reasonable control over the sleep environment--sufficient “down time”)
  - “sleep manager” is on hand and/or persons are monitored, particularly in hazardous environments

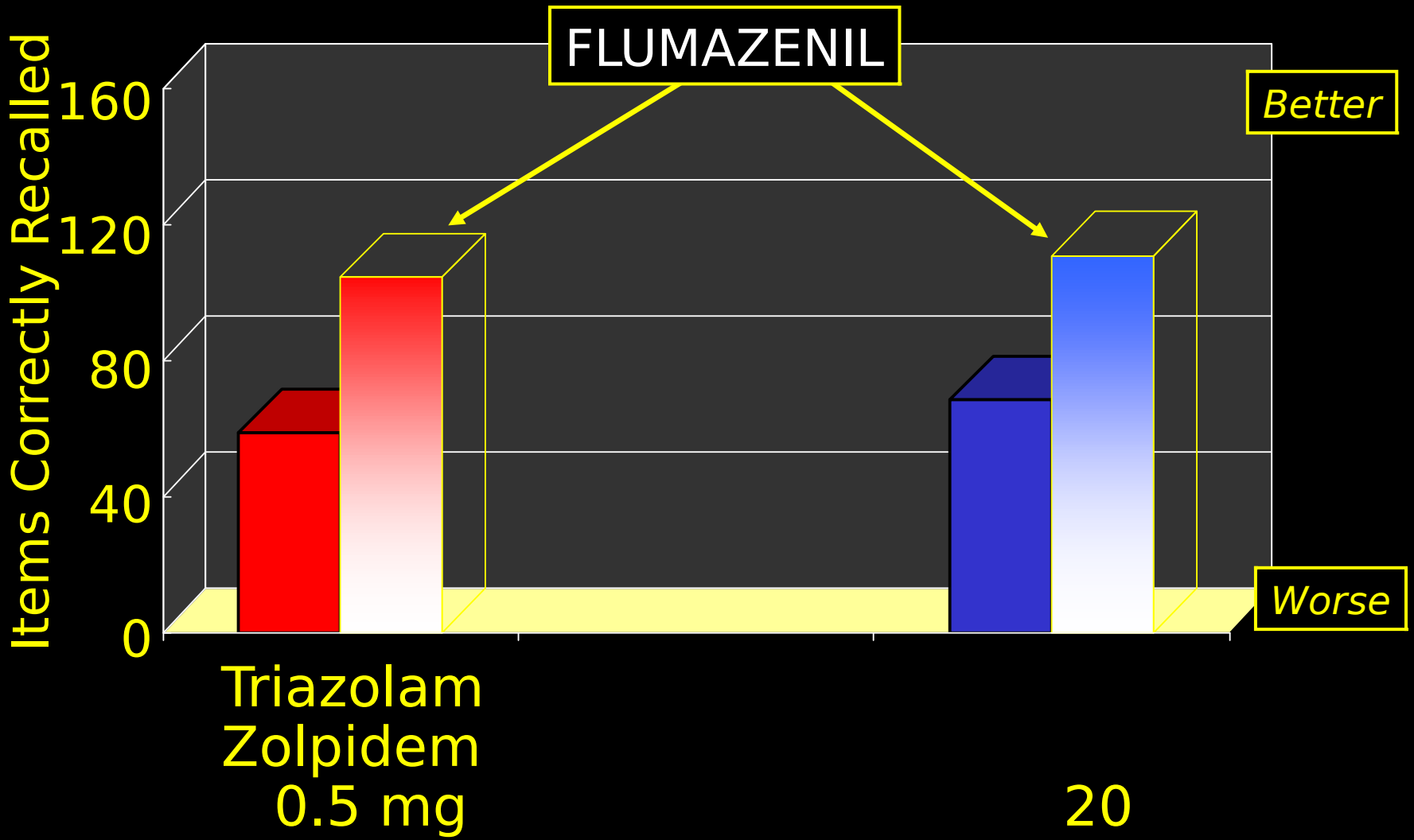
Sleep-Inducing Agents: RECOMMENDATIONS

- Dose according to label. EXAMPLES:
  - **Triazolam (Halcion®)** - 0.25 mg, 30 minutes prior to bedtime
  - **Zolpidem (Ambien®)** - 10 mg, 30 minutes prior to bedtime
- Higher doses may be required in young, healthy adults and/or under particularly non-conducive conditions

Sleep-Inducing Agents: Can we Eliminate their Negative Effects?

- ALL sleep-inducing agents will impair mental performance at peak effect
- Caffeine is only partially effective in reversing these negative effects (different brain receptor)
- BLOCK sleep-inducing agents at their receptor in the brain?

Flumazenil Blocks Memory Impairments caused by Triazolam & Zolpidem



FUTURE DIRECTIONS

- Fieldable Product: 2-drug combination
- Oral formulation = sleep-induction --->elective sleep termination agent:

SIESTA

Improving Sleep: What about Melatonin? THE GOOD STUFF

- Hastens resynchrony of body temperature rhythm with new local time
- People report that it makes them “feel better” and “sleep better” (subjective effects)
- Shortens time taken to fall asleep (objective effect)

Improving Sleep: What about Melatonin? THE QUESTIONABLE STUFF

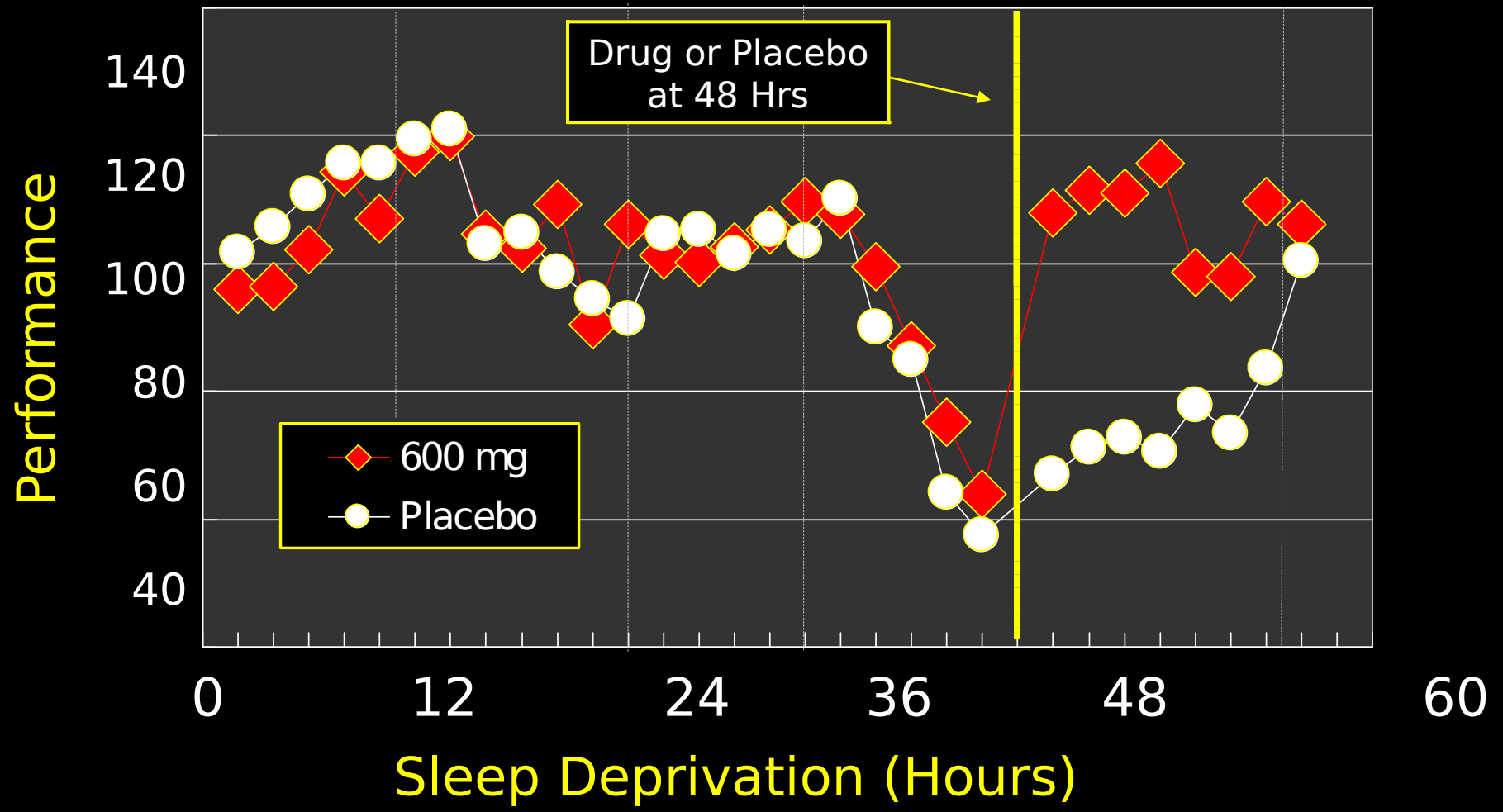
- Must be taken at correct time of day to resynchronize body temperature in appropriate direction:
  - east-bound flight: take melatonin late afternoon of new local time (possibly impairing mental operations)
- Objective sleep-***maintaining*** effects are weak compared to prescription sleep-inducing agents
- No evidence that melatonin ***objectively*** improves next-day mental performance
- Side effects, long-term effects, minimum effective dosage unknown

Strategies for Improving Mental Operations when Sleep is Not Possible:

CNS STIMULANTS

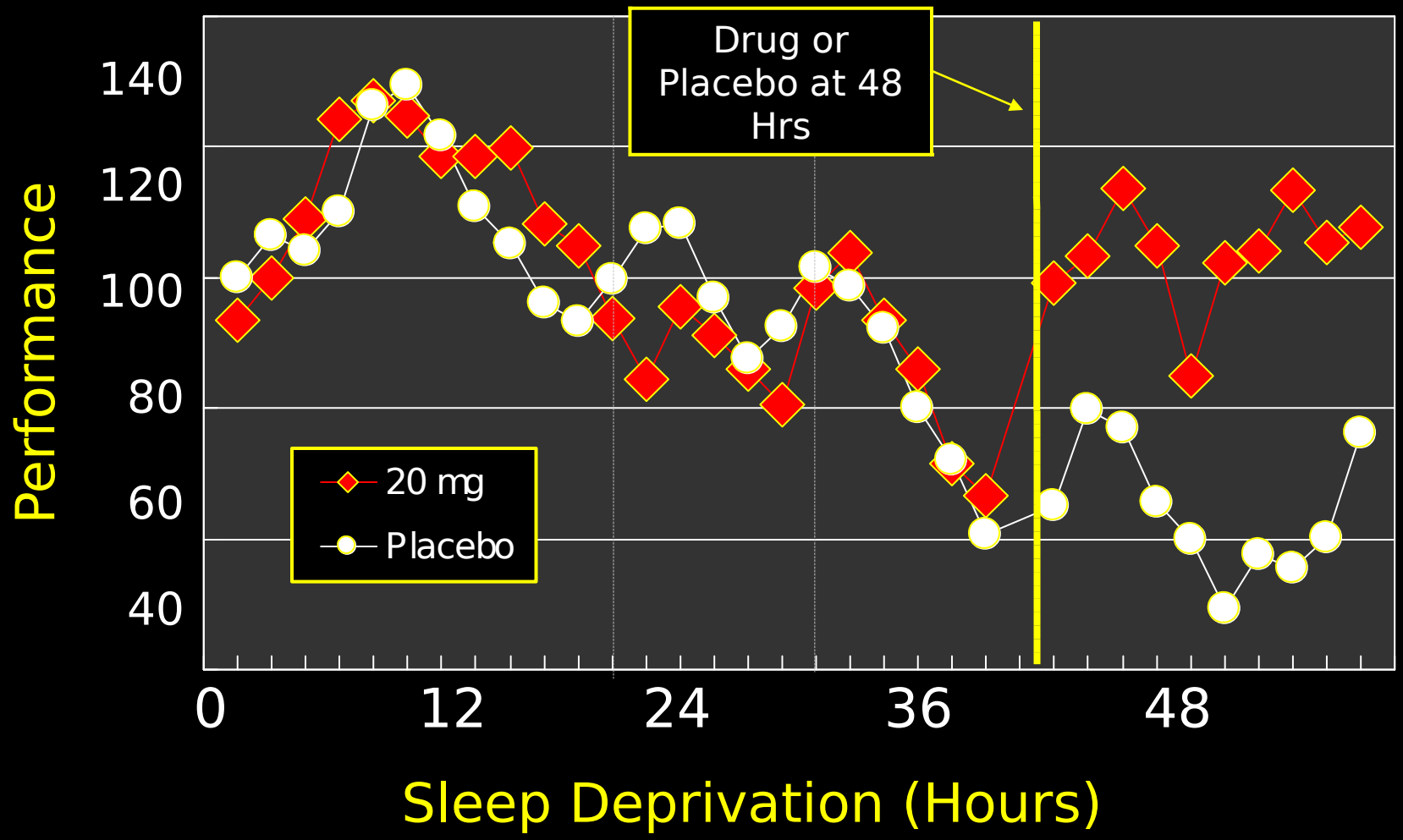
CAFFEINE 600 mg

Effects on Mental Operations



d-AMPHETAMINE 20 mg

Effects on Mental Operations



Nicotine and l-Deprenyl Effects
SUMMARY

- Did not improve objective alertness
- Only slightly and temporarily improved mental operations
- Did not improve self-ratings of mood
- Nicotine caused nausea in some subjects
- “Go-juice”: poor strategy for maintaining alertness and mental performance

Stimulant Use in Sustained Operations: RECOMMENDATION

- Use only to “postpone” sleep up to 12 hours, NOT replace sleep
- Caffeine:
  - Pills (Vivarin®, No-Doz®)
  - Gum (StayAlert®)
  - Bar

FUTURE DIRECTIONS - MODAFINIL

- Indication: improving alertness in narcoleptics
- Mechanism of action?
- Enhances alertness; improves performance?
- Better than currently available stimulants? (tolerance, abuse potential, mental performance, recovery sleep)
- Evaluate modafinil during sleep deprivation

Strategies for Improving Mental Operations when Sleep is Not Possible:

BEHAVIORAL STRATEGIES

What about LIGHT EXPOSURE?

- IDEA: Time light exposure to stimulate the “phase advance” or “phase delay” portion of the phase response curve
- Sitting in front of a light lamp at specified times is impractical
- Wearing dark sunglasses to prevent light exposure at inappropriate times - is probably do-able
- PROBLEM: may be impractical to implement
- No evidence that bright light exposure substantially and consistently improves mental operations

Strategies that Temporarily (< 30 min Duration) Improve Alertness During Sleep Loss

- Loud Noises (radio music)
- Cold air (rolling windows down, AC)
- Physical Exercise
- Bright Light

"…AIR and RADIO are at best only temporary expedients to reduce…sleepiness, perhaps enabling [individuals] to find a suitable place to stop, take a break and avail themselves of caffeine and a nap."

**Adapted from Reyner & Horne, 1998*

SUMMARY

- Sleep sustains military effectiveness
- The sleep-deprived person is the worst judge of his/her own effectiveness
- Sleep deprivation (total, partial or due to disruption, circadian desynchrony):
  - decreases one's ability to stay awake under non-stimulating conditions
  - impairs higher-order mental operations (even in a stimulating situation)
- Current best solution: improve/increase sleep via both nonpharmacological and pharmacological means

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